A MANUAL OF PUBLIC HEALTH

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OF

PUBLIC HEALTH

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PREFACE

In the following pages the author has interwoven knowledge compiled from various sources with his personal official experience in both urban and rural districts.

In the plan of the work and in its treatment he may perhaps claim some originality; at all events it is intended to convey the author's idea of the subjects of special knowledge necessary for those engaged in either an administrative or subordinate capacity in the Public Health Service to be acquainted with.

The author has to thank Mr. Henry Law, M. Inst. C.E., for revising the statistical section and the mathematical formulæ, and for the useful tables at pages 217 and 218; to Professor Fuller the author is indebted for the scale at page 36; to Dr. Richard Budd, of Barnstaple, for the loan of original photographs and drawings; to Professor Stewart, of the Royal College of Surgeons, for facilities for copying pathological specimens in the Museum; and to Mrs. Wynter Blyth for drawing and colouring most of the lithographs.

CONTENTS

SECTION I.—*STATISTICS.*

CHAPTER I.

THE CALCULATION AND SIGNIFICANCE OF VITAL STATISTICS.

CHAPTER II.

MEAN AGE AT DEATH—MEAN DURATION OF LIFE—PROBABLE DURATION OF LIFE —CONSTRUCTION OF LIFE TABLES.

CHAPTER III.

AIDS TO CALCULATION.

SECTION II.—*AIR—VENTILATION—WARMING.*

CHAPTER IV.

AIR.

CHAPTER V.

THE GENERAL PRINCIPLES OF VENTILATION.

Methods of Ventilation.

CHAPTER VI.

SYSTEMS OF VENTILATION COMBINED WITH WARMING OR DEPENDENT ON MECHANICAL AGENCIES.

CHAPTER VII.

WARMING.

CHAPTER VIII.

PRACTICAL EXAMINATION OF AIR.

CHAPTER IX.

HOW TO MEASURE CUBIC SPACE AND TO REPORT ON VENTILATION.

SECTION III.—*METEOROLOGY.*

CHAPTER X.

THE BAROMETER.

CHAPTER XI.

THE DEW-POINT—RAINFALL—SUNSHINE—WIND.

SECTION IV.—*WATER SUPPLY.*

CHAPTER XII.

SOURCES OF WATER SUPPLY.

CHAPTER XIII.

THE WATER SUPPLY OF THE METROPOLIS.

CHAPTER XIV.

THE SCIENTIFIC EXAMINATION OF WATER.

SECTION V.—*DRAINS—SEWERS—SEWAGE DISPOSAL.*

CHAPTER XV.

DRAINS.

CHAPTER XVI.

SEWERS.

CHAPTER XVII.

THE SEWERAGE OF THE METROPOLIS.

CHAPTER XVIII.

CALCULATIONS OF THE DISCHARGE OF SEWAGE OR WATER OR OTHER LIQUIDS.

CHAPTER XIX.

DISPOSAL OF SEWAGE.

SECTION VI.—*NUISANCES.*

CHAPTER XX.

ORDINARY NUISANCES DEALT WITH BY SANITARY AUTHORITIES.

CHAPTER XXI.

EFFLUVIUM NUISANCES CONNECTED WITH TRADES.

SECTION VII.—*DISINFECTION—DISINFECTANTS.*

CHAPTER XXII.

EXPERIMENTAL METHODS FOR TESTING THE VALUE OF A DISINFECTANT.

CHAPTER XXIII.

DISINFECTION BY HEAT.

CHAPTER XXIV.

CHEMICAL DISINFECTANTS.

The Halogens.

SECTION VIII.—*ZYMOTIC (MICRO-PARASITIC) DISEASES.*

CHAPTER XXV.

THE MODERN THEORY OF MICRO-PARASITES.

CHAPTER XXVI.

ERUPTIVE FEVERS, SMALL-POX, MEASLES, SCARLET FEVER AND TYPHUS.

Small-Pox.

Measles.

Scarlet Fever.

Typhus.

CHAPTER XXVII.

MICRO-PARASITIC DISEASES AFFECTING THE NERVOUS SYSTEM—RABIES—TETANUS—WHOOPING COUGH.

Tetanus.

Whooping Cough.

CHAPTER XXVIII.

MICRO-PARASITIC DISEASES MAINLY AFFECTING THE RESPIRATORY ORGANS.

Pneumonia.

CHAPTER XXIX.

SEPTICÆMIC MALADIES.

Erysipelas.

Diphtheria.

Puerperal Fever—Septicæmia—Pyæmia—Blood-Poisoning.

CHAPTER XXX.

TUBERCULAR MALADIES.

Tuberculosis.

CHAPTER XXXI.

MALARIA—MALARIOUS DISEASES.

CHAPTER XXXII.

MICRO-PARASITIC DISEASES MAINLY ATTACKING THE INTESTINE.

Enteric or Typhoid Fever.

Asiatic Cholera.

SECTION IX.—*ISOLATION HOSPITALS.*

CHAPTER XXXIII.

THE PRINCIPLES OF CONSTRUCTION OF ISOLATION HOSPITALS.

SECTION X.—*FOOD—DIET.*

CHAPTER XXXIV.

THE PRINCIPLES OF DIET.

SECTION XI.—*THE DUTIES OF SANITARY OFFICERS.*

CHAPTER XXXV.

DUTIES AND QUALIFICATIONS OF MEDICAL OFFICERS OF HEALTH.

SECTION XII.—*INSPECTION OF FOOD.*

CHAPTER XXXVI.

THE INSPECTION AND SEIZURE OF UNWHOLESOME FOOD.

CHAPTER XXXVII.

POISONOUS FOOD.

CHAPTER XXXVIII.

UNFIT VEGETABLE SUBSTANCES.

CHAPTER XXXIX.

INSPECTION OF FISH AND MEAT.

CHAPTER XL.

DISEASES OF ANIMALS RENDERING THEIR FLESH MORE OR LESS UNFIT FOR FOOD.

LIST OF ILLUSTRATIONS

PLATES AND DIAGRAMS

SECTION I.

STATISTICS.

A MANUAL OF PUBLIC HEALTH.

CHAPTER I.

THE CALCULATION AND SIGNIFICANCE OF VITAL STATISTICS.

VITAL STATISTICS have been defined as the science of figures applied to life; the term was first invented by Professor Achenwall, of Göttingen; the science itself by Sir William Petty, who died in 1687.

The materials for the statistics of the health officer are the census returns, any local census which he may make, and returns from the registrars or other persons.

(1) *Method of Calculating Populations between the Census Periods.*

The ten-year period census is far too long, and in certain rapidly growing or decreasing localities, causes great errors in the calculated rates, whenever such increase or decrease is irregular. If, however, the change is fairly uniform, the population may in any year in the interval between two censuses, be approximately calculated by the following rule.

From the logarithm[1] of the most recent census subtract the logarithm of the previous census, and divide the number so obtained by the number of intervening years; the quotient will be

[1] It is difficult and cumbersome to use ordinary arithmetic in the calculation of a variety of data which the sanitarian requires, hence a knowledge of the use of logarithms is essential. Law's *Mathematical Tables* (Crosby, Lockwood, and Son) are very clear and the directions simple. Woodward's *Logarithms* and Chambers's *Tables* may also be recommended.

the logarithm of the ratio of annual increase. By adding this logarithm to the logarithm of the population at any period, the logarithm of the population at the end of the succeeding year will be obtained; and by continually adding the logarithm of the ratio, the logarithm of the population in each successive year will be obtained.[1]

For example, supposing that in 1886 it is required to calculate the population of a town, for each year from 1881, the census in 1871 giving 156,000, and in 1881 giving 171,000. Then

Logarithm of 171,000 = 5·232996
„ 156,000 = 5·193125

0·039871 ÷ 10 = ·003987 = the logarithm of ratio of increase.

Then log. of 171,000 =	5·232996				
	0·003987				
	5·236983	No.	172,580	population in	1882.[2]
	0·003987				
	5·240970	„	174,170	„	„ 1883.
	0·003987				
	5·244957	„	175,780	„	„ 1884.
	0·003987				
	5·248944	„	177,400	„	„ 1885.
	0·003987				
	5·252931	„	179,030	„	„ 1886.

[1] Let p denote the population at any time; p' the population at any previous time n the number of intervening years; then $\sqrt[n]{\frac{p}{p'}} = r = 1 +$ the annual rate of increase. The division of the logarithm of 2 or 3 by the logarithm of r gives the number of years in which at *that* rate the population will double or triple, &c. (Farr).

[2] The census is taken in March, therefore the numbers obtained would be the presumed population in the March of the different years; but if it is required to estimate for the middle of each year, we must begin by adding ¼th of the logarithm ·0039871 to the 1881 population, which will then represent the logarithm of the population in the middle of 1881; by then adding to the logarithm of each succeeding year the logarithm ·0039871, the logarithms of the population in the middle of each year are obtained. Similarly, if the population in the September quarter is required, then we must begin by adding half the logarithm ·0039871 to the 1881 population.

Or, if any one year is required, all that is necessary is to multiply the logarithm of the ratio of annual increase by the number of years elapsed from the census, and add it to the logarithm of the population; thus, if the population is required for 1888, $\cdot0039871 \times 7$ and added to $5\cdot232996$ gives the logarithm $5\cdot260906$, that is 182,350.

On the other hand, supposing the census of 1881 gave a lower figure than that of 1871, the population for the years subsequent to 1881 may then be similarly calculated upon the assumption of a uniform decrease.

(2) *Local Censuses.*

These may be made in small areas, such as a crowded street, model artisans' dwellings, and villages, by the inspector of nuisances, and will be found of value, the more especially if made at short intervals.

If an accurate enumeration of persons be made in 100 houses of the same size and class, trustworthy averages may be obtained; and such averages may be used for the purpose of calculating the population of small areas. The number of houses can be got from the rate-books, and the number of empty houses from the rate-collectors; the inhabited houses are then multiplied by the average. It is obvious that this method does not give age distribution, and is inferior to personal inquiry, but it is nevertheless useful, for it is not always practicable to make an actual local census.

(3) *Death Returns.*

It is the duty of every sanitary authority to cause the local registrars to supply the officer of health regularly with copies of the death returns and also the number of births. These returns are usually made weekly, but deaths from zymotic diseases should of course be communicated as soon as the registrar has notice of the fact; this is the more necessary in those places in which the compulsory notification of disease is not in force; where infectious disease is systematically notified, the health officer will be early acquainted with the nature and locality of the disease.

An example of the most useful form of return is the following :—

DISTRICT________________ N.B.—This Return is to be posted in time to secure its delivery by THE FIRST POST ON MONDAY MORNING.

SUB-DISTRICT________________

A Return of the number of Births and of Deaths registered in the Sub-District during the Week ending Saturday, the day of 189 .

BIRTHS.	DEATHS.
Males	Males ....
Females	Females ....
TOTAL	TOTAL ....
Write "NIL" if no Birth was Registered in the week.	Write "NIL" if no Death was Registered in the week.

PARTICULARS OF THE DEATHS REGISTERED IN THE WEEK.

No. of Entry in Register.	WHEN DIED AND WHERE. State also in Col. 9 the previous residence of inmates of Institutions : See General Instruction No. 3, and Special Instruction No. 9.	SEX.	AGE.			OCCUPATION OR PROFESSION.	CAUSE OF DEATH.	INQUEST CASES.	OBSERVATIONS. (See Instructions, General No. 3, and Special No. 9.)
			Under 1 Year.	1 and under 60.	60 years and upwards.				
Cols.	1.	2.	3.	4.	5.	6.	7.	8.	9.

This return gives the following items of information :—

Total number of births, male and female, for the week; total number of deaths, male and female; date of death; address of place of death; sex, age, and occupation of person dying;—added to which the registrar notes when an inquest has been held. All these different facts admit of tabulation and arrangement.

(4) *Causes of Death.*

The causes of death and the ages at death are usually collected together and tabulated in the following form :—

TABLE I.

Mortality of the District of for the Weeks ending 18 .

Under 5 years.	Causes of Death.	Ages. 0 and under 20.	20 and under 40.	40 and under 60.	60 and under 80.	80 and above.	Total.
	I. ZYMOTIC.						
	ORDER 1—MIASMATIC.						
	Small-pox						
	Measles						
	Scarlatina (Scarlet Fever)						
	Diphtheria						
	Quinsy						
	Croup						
	Whooping Cough						
	Typhus						
	Enteric or Typhoid Fever						
	Simple Continued Fever						
	Erysipelas (Rose)						
	Puerperal Fever (Metria)						
	Carbuncle						
	Influenza						
	Dysentery						
	Diarrhœa (Bowel Complaint) . . .						
	Cholera (Simple)						
	Ague						
	Remittent Fever						
	Rheumatism						
	Other *Zymotic* Diseases . . .						
	ORDER 2—ENTHETIC.						
	Syphilis						
	Stricture of Urethra						
	Hydrophobia						
	Glanders						
	ORDER 3—DIETETIC.						
	Privation						
	Want of Breast Milk						
	Purpura and Scurvy						
	Alcoholism { Delirium Tremens . .						
	Alcoholism { Intemperance . . .						
	Carried forward . . .						

TABLE I. (*continued*).

Under 5 years.	Causes of Death.	Ages. 0 and under 20.	20 and under 40.	40 and under 60.	60 and under 80.	80 and above.	Total.
	Brought forward . .						
	ORDER 4—PARASITIC.						
	Thrush						
	Worms, &c.						
	II. CONSTITUTIONAL.						
	ORDER 1—DIATHETIC.						
	Gout						
	Dropsy						
	Cancer						
	Noma (Cancrum Oris)						
	Mortification						
	Abscess or Tumour						
	ORDER 2—TUBERCULAR.						
	Scrofula						
	Tabes Mesenterica						
	Phthisis (Consumption)						
	Hydrocephalus (Water on the Brain) .						
	III. LOCAL.						
	ORDER 1—NERVOUS SYSTEM.						
	Cephalitis						
	Apoplexy						
	Paralysis						
	Insanity						
	Chorea						
	Epilepsy						
	Convulsions						
	Brain Disease, &c.						
	ORDER 2—ORGANS OF CIRCULATION.						
	Pericarditis						
	Aneurism						
	Heart Disease, &c.						
	ORDER 3—RESPIRATORY ORGANS.						
	Laryngitis						
	Bronchitis						
	Pleurisy						
	Pneumonia						
	Asthma						
	Lung Disease, &c.						
	Carried forward . . .						

TABLE I. (*continued*).

Under 5 years.	Causes of Death.	Ages. 0 and under 20.	20 and under 40.	40 and under 60.	60 and under 80.	80 and above.	Total.
	Brought forward . .						
	ORDER 4—DIGESTIVE ORGANS.						
	Gastritis						
	Enteritis						
	Peritonitis						
	Ascites						
	Ulceration of Intestines						
	Hernia (Rupture)						
	Ileus						
	Intussusception						
	Stricture of Intestines						
	Fistula						
	Stomach Disease, &c.						
	Pancreas Disease, &c.						
	Lead Colic						
	Jaundice						
	Hepatitis						
	Liver Disease, &c.						
	Spleen Disease, &c.						
	ORDER 5—URINARY ORGANS.						
	Nephritis						
	Ischuria						
	Nephria (Bright's Disease) . . .						
	Diabetes						
	Stone (Calculus)						
	Cystitis						
	Kidney Disease, &c.						
	ORDER 6—ORGANS OF GENERATION.						
	Ovarian Dropsy						
	Uterus Disease, &c.						
	ORDER 7—ORGANS OF LOCOMOTION.						
	Arthritis (Synovitis)						
	Joint Disease, &c.						
	ORDER 8—INTEGUMENTARY SYSTEM.						
	Phlegmon						
	Ulcer						
	Skin Disease, &c.						
	Carried forward . . .						

TABLE I. (*continued*).

Under 5 years.	Causes of Death.	Ages. 0 and under 20.	20 and under 40.	40 and under 60.	60 and under 80.	80 and above.	Total.
	Brought forward						
	IV. DEVELOPMENTAL.						
	ORDER 1—DISEASES OF CHILDREN.						
	Premature Birth						
	Cyanosis						
	Spina Bifida						
	Other Malformations						
	Teething						
	ORDER 2—DISEASES OF ADULTS.						
	Childbirth (see Puerperal Fever)						
	ORDER 3—DISEASES OF OLD PEOPLE.						
	Old Age						
	Premature Decay						
	ORDER 4—DISEASES OF NUTRITION.						
	Atrophy and Debility						
	V. VIOLENT DEATHS.						
	ORDER 1—ACCIDENTS OR NEGLIGENCE.						
	Fractures and Contusions						
	Wounds { Gun Shot, Cut, Stab						
	Burns and Scalds						
	Poison						
	Drowning						
	Suffocation						
	Otherwise						
	ORDER 3—HOMICIDE.						
	Murder and Manslaughter						
	ORDER 4—SUICIDE.						
	Wounds { Gun Shot, Cut, Stab						
	Poison						
	Drowning						
	Hanging						
	Otherwise						
	Violent Deaths not Classed						
	NOT SPECIFIED, OR ILL DEFINED						
	TOTAL						

To those acquainted with the recent great advances in etiology the table has little commendable in either arrangement or classification. For example, neither phthisis nor cancer can properly be called constitutional; the former most decidedly has affinities with zymotic maladies, being caused by a definite parasite; tabes is produced by the same parasite; pneumonia, syphilis, and possibly tetanus, should be also classified among parasitic maladies. In a few years there will of necessity be a different and more scientific classification,[1] but the subject is too large to be discussed here, and the table will do as well as any other for the purpose of exemplifying the usual methods of tabulating statistics.

In extracting individual deaths from the returns it is convenient in the first place to denote them by single strokes, with a cross stroke for the fifth, thus 12 deaths from pneumonia of persons between 20 and 40 would be represented thus: 𝍸 𝍸 ||. In the final sheet these marks are, of course, exchanged for ordinary figures. It will also be found useful after entry of any death to put a pencil tick or cross opposite the entry in the return, otherwise mistakes in enumeration may occur.

(5) *Addresses—The Mortality Ledger.*

A mortality ledger is an essential for every district. A mortality ledger is a large bound volume, each page of which is similarly tabulated to the registrar's returns. To each street, village, or small definite locality is assigned one or several pages, in which the deaths of that particular locality are copied. On the top of the page is written clearly the name of the street or locality, and it is convenient to put also the character of the houses, the general nature of the inhabitants, and the actual or presumed population. From 25 to 30 deaths should fill a page, and every fifth line should be double, so that deaths can then be easily enumerated. The ledger is, of course, indexed. A properly kept mortality ledger is of the greatest use, for by its means the health officer is able at any moment to refer to the mortality statistics of the smallest hamlet, court, or street in his district. The following

[1] For an essay at scientific classification the reader may consult *Public Health*, vol. ii. p. 289.

is a copy of a portion of a single sheet from one of the author's "mortality ledgers":—

EAST STREET. { No. of houses 105. Most of the street let out in tenements.
No. of rooms 940. Births for 5 years ending 1885 = 377.

Population by local census in 1883—
Adults 1016
Children below 15 . 626

1642

No. of House.	Date.	Sex.	Age.			Occupation or Profession.	Cause of Death.
			Under 1.	1 and under 60.	60 and upwards.		
	1877.						
97	21.6	F.	5 months			Carman's daughter.	Diarrhœa.
10	6.7	M.		22		Carman.	Phthisis.
89	9.7	M.		2		French polisher's son.	Pertussis.
55	12.7	M.			75	Plumber.	Paralysis.
14	3.8	M.		59		Carman.	Phthisis.

(6) *Sex.*

If so desired, the causes of death or other facts can be collected for each sex separately. In certain districts it is well this should be done, the more especially where there are industrial influences affecting unequally the health of males and females. The death-rate is also affected by inequality in numbers between males and females, the latter having a lower normal death-rate than the former (see Table II., p. 16).

(7) *Age.*

A division into a few age periods only, as in the table at p. 7, is sufficient for general purposes, but if a life table is to be constructed, then a further division is necessary.

(8) *Calculation of Birth and Death Rates.*

In the first place the data must be made as correct as possible. Should there be a lying-in institution in the district, the births of strangers must be eliminated; similarly persons who are strangers to the district, but die there, whether in hospitals or private houses, must also be eliminated; and residents who, having contracted their fatal maladies in the district and die elsewhere, must be added, so far as such deaths can be ascertained. In the

metropolis there is an excellent arrangement in force, by means of which, for a small payment, each local authority obtains returns direct from the Registrar-General's Office, of extra-parochial deaths in various hospitals, infirmaries, asylums, and similar public institutions.

Birth and death rates are expressed in terms per 1,000 per year of the known or calculated population. If the whole of the statistics relate to a single year, the calculation is a simple rule of three sum, the rule being—multiply the number of deaths by 1,000, and divide by the population. For example, in a population of 156,290 there were in one year 2,989 deaths; then $\frac{2{,}989{,}000}{156{,}290} = 19{\cdot}1$. The death-rate is therefore 19·1 per 1,000 per annum; or, if done by logarithms, subtract the logarithm of the deaths from the logarithm of the population multiplied by 1,000; thus—

$$\begin{array}{ll} \text{Logarithm of } 2{,}989{,}000 = & 6{\cdot}47553 \\ \text{Logarithm of } \quad 156{,}290 = & 5{\cdot}19393 \\ \hline & 1{\cdot}28160, \text{ or } 19{\cdot}1. \end{array}$$

The same result is of course obtained by the multiplication of a factor (reciprocal) obtained by dividing 1,000 by the population and multiplying the quotient by the number of deaths; thus, in the example given: $\frac{1{,}000}{156{,}290} = {\cdot}006398$, and $\cdot006398 \times 2{,}989 = 19{\cdot}1$; or, by the use of logarithms, the logarithm of the factor is added to the logarithm of the deaths; thus—

$$\begin{array}{ll} \text{Logarithm of } {\cdot}006398 = & \bar{3}{\cdot}80607 \\ \text{Logarithm of } 2{,}989 \quad = & 3{\cdot}47553 \\ \hline & 1{\cdot}28160 = 19{\cdot}1. \end{array}$$

The operation is not so simple if it is desired to express *accurately* the mortality of a week, a month, or a quarter, as a yearly rate, for it is necessary to take into account that a week is not exactly the fifty-second part of a year, that a month varies in length, and that the number of days in a quarter is from 90 to 92. The number of days in a natural year is 365·24, the number of weeks 52·177; therefore the number of deaths in a week, multiplied by this number, and then by 1,000, and lastly divided by

the population, gives the annual rate. A more convenient method is to divide the estimated population by 52·177, and in this way a number is obtained which represents the weekly population, and which serves as a constant throughout the year. To obtain the death-rate, the number of deaths is divided by this number, and the resulting fraction multiplied by 1,000; *e.g.* in a population of 132,450 persons there died, in the week ending July 28, 51 persons; required the annual death-rate for the week.

First method—

$$\frac{51 \times 52{\cdot}177 \times 1{,}000}{123{,}450} = 21{\cdot}55 \text{ death-rate.}$$

Second method—

$\frac{123{,}450}{52{\cdot}177} = 2{,}366$ weekly population, and $\frac{51 \times 1{,}000}{2{,}366} = 21{\cdot}55$ death-rate.

It must, however, be confessed that for practical purposes the deaths in a week may be calculated on the basis of 52 weeks in the year, the errors of delayed registration far outweighing the refinements of the decimals given above.

But with regard to rates based upon monthly returns, to multiply births or deaths by 12 will always produce a considerable error, because some months have four weeks, others five.

The method generally adopted is to divide the population by the number of days in the year, which then gives the daily population, or $\frac{\text{population}}{365{\cdot}24} = \text{daily population}$. This number must then be multiplied by the number of days in a month, 28 or 31 as the case may be, which will give the theoretical population for that month. For example, if in a population of 123,450 persons there should die, in the four weeks ending February 28, 210 persons, the calculation proceeds as follows: $\frac{123{,}450}{365{\cdot}24} = 338$, the daily population. Then $338 \times 28 = 9{,}464$, which is the population for 28 days; then comes the usual calculation $\frac{210 \times 1{,}000}{9{,}464} = 22{\cdot}19$; or get out the factor $\frac{1000}{9464} = {\cdot}1056$, and ${\cdot}1056 \times 210 = 22{\cdot}18$, which is near enough.

Factors (reciprocals)[1] will in all these cases be found most convenient, and the factor need seldom be more than three figures. For instance, the month of 28 days gives a factor for All Souls, in the writer's district, of ·4879, and supposing in the month there are 56 births, then $56 \times {}·4879$ = birth-rate 27·32, but the same result is obtained by multiplying by ·488; similarly a factor of ·8909 may be transformed into ·891, or a factor of ·561 may even be made into two figures, viz. ·56, without introducing inaccuracy of great moment.[2]

In the same way the daily population may be converted into the population for a quarter by multiplying by either 90 or 92 as the case may be; but the error in taking three months as exactly a quarter of a year, is immaterial, and rates may for this purpose be calculated by simply multiplying the births or deaths by 4×1000, and dividing by the population.

(9) *Age Distribution.*

A rate derived from a population of every age from the newly-born to the limit of human existence gives but scanty information. The normal death-rate below 5 is something like 66 per 1000, between 10 and 15 it sinks to 5, persons over 85 die at the rate of 294 per 1000; it is therefore evident that should a district from the presence of institutions for the aged or the very young have a number of the less vital members of the community in excess of other districts, the death-rate will be large; but such a rate, unless beyond or below the normal rates for those age-periods, affords

[1] A table of reciprocals of numbers from 1 to 100,000, with their differences, by which the reciprocals of numbers may be obtained up to 10,000,000, by Lieut.-Col. W. H. Oakes, is published by Messrs. C. and E. Layton, London, and will be found most useful.

[2] Mr. Sydney Lupton writing in *Nature* observes :—"It is convenient to bear in mind the following simple rules, due I believe to De Morgan. If two numbers, a and b, each true to the first decimal place, are multiplied together, the result is true to $\frac{a+b}{20}$ only; a second true decimal in each number makes the result ten times more correct, and so on. In dividing $\frac{a}{b}$ where each is true to the first place, the result is true to $\frac{a+b}{b^2 \times 20}$, and so on. Any attempt at greater accuracy in calculation than is indicated by these results should be avoided, since it only precludes the use of cheap and handy tables, tires the calculator, making him more liable to error in the important figures, and tends to give a false idea of the accuracy of the experiments on which the calculations are based."

no guide to sanitary condition—it will depend upon "the age distribution"; similarly in localities in which from various industrial and other causes, there is an excess of persons between the ages 10 and 35, the mortality will seem very low if compared with more mixed populations. It follows, then, that all rates of mortality should be dissected up and expressed in terms per 1000 of various groups of ages. This is done in the following table, which exhibits the death-rates at different age-periods (calculated from the numbers living at each age-period) amongst males and females in England and Wales during the ten years 1871–1880 :—

TABLE II.

ANNUAL MORTALITY PER 1,000.

	Males.	Females.
All ages	22·61	20·00
Under 5 years	68·14	58·10
5 to 10 ,, ...	6·67	6·20
10 ,, 15 ,, ...	3·69	3·70
15 ,, 20 ,, ...	5·23	5·43
20 ,, 25 ,, ...	7·32	6·78
25 ,, 35 ,, ...	9·30	8·58
35 ,, 45 ,, ...	13·74	11·58
45 ,, 55 ,, ...	20·05	15·59
55 ,, 65 ,, ...	34·76	28·54
65 ,, 75 ,, ...	69·57	60·82
75 and upwards	169·08	155·83

(*Supplement to the* 45*th Annual Report of the Registrar-General.*)

The following table gives the age-distribution amongst 1,000 persons in England and Wales (mean of the censuses of 1871 and 1881) :—

TABLE III.

All Ages	Under 5	5—10	10—15	15—20	20—25	25—35
1,000	136	120	107	97	89	147

All Ages	35—45	45—55	55—65	65—75	75 and upwards.
1,000	113	86	59	33	13

That is, persons under 5 form 13·6 per cent. of the total populations; persons aged 5 to 35 form 75·9 per cent.; and persons aged 55 and upwards form 10·5 per cent.

Since 1883 the Registrar-General, in his annual summaries for London and other great towns, has given the corrections which must be applied to the death-rates for age and sex distribution, so as to make the urban death-rates comparable with that of the country (England and Wales) as a whole. Out of the 28 towns, the correction adds in 26 a certain quantity to the recorded rate, varying from 0·5 to 3 per 1000; whilst in two towns—Norwich and Plymouth—a small subtraction must be made from the recorded rates. The correction for London is + 1·3 per 1,000; or the death-rate in any year must be multiplied by the factor 1·0615. The method pursued by the Registrar-General is as follows:—The mean annual death-rate for each sex, at each of the 12 age-periods, in England and Wales in 1871–80, is applied to the population of each of the 28 towns, with age and sex distribution as shown at the last census (1881). The result is a number called the *standard rate*, which varies in every town according to the age and sex distribution of the population of the town. The mean annual death-rate of England and Wales from 1871–80 (21·27) is then divided by this standard, and a factor is obtained for each town by which the recorded death-rate of any year must be multiplied. The factor exceeds unity in 26 towns, and is less than unity for two towns only out of the 28 (*Annual Summary for* 1883).

It is not necessary to fractionate up the routine statistics of a district into so many divisions as represented in the foregoing table. I am content with regard to the statistics of my own district with five groups of ages. The following, for instance, is a table of rates at different ages for St. Marylebone during 1886; the natural values taken from the English life table being added for comparison.

These numbers are obtained in a similar manner to the death-rates of the whole population already detailed at p. 14. The population at the groups of ages dealt with are extracted from the census returns; the deaths at that particular age-period collected from such a table as at p. 7, × 1,000, and divided by the population for that age. If the calculation is made for any fraction of a year, the rules given at p. 14 equally apply. For example, the deaths for the

TABLE IV.

COMPARING THE DEATH-RATES FOR 1886 AT VARIOUS AGES, WITH DEATH-RATES AT THE SAME AGE GIVEN IN THE ENGLISH LIFE TABLE.

	Under 5 years of age.	5 and under 20.	20 and under 40.	40 and under 60.	60 and upwards.
English Life Table	65·7	7·1	10·3	18·3	71·7
The whole district	70·2	3·3	6·8	20·8	68·3
All Souls	73·8	4·3	9·1	21·1	72·8
Cavendish Square	41·9	2·0	2·2	13·8	68·4
Rectory	70·6	3·5	7·4	23·1	46·1
St. Mary	72·3	1·9	6·3	20·8	60·4
Christ Church	89·4	4·1	8·2	23·9	81·6
St. John	60·1	3·0	6·4	17·6	70·5

whole district between the ages of 20 and 40 were 395, the calculated population at those ages was 57,746, hence $\frac{395 \times 1{,}000}{57{,}746} = 6{\cdot}8$.

In the intervals between the census the population at any age in increasing or decreasing populations must be calculated. For example, a population in 1881 of 154,910 contained 15,900 under 5 years of age; in 1886 the same population was presumed from calculation to be 156,290: then by an ordinary rule of three sum $\frac{15{,}900 \times 156{,}290}{154{,}910} = 16{,}035$ population under 5 years in 1886, and so on for the remaining groups.

(10) *Zymotic Death-Rate.*

What is called the zymotic death-rate, is the rate of mortality per 1,000 of the population from the principal zymotic diseases—that is, small-pox, measles, scarlet fever, diphtheria, whooping cough, erysipelas, typhoid, typhus, and other forms of fever and diarrhœa. The calculation is precisely the same as that of an ordinary death-rate. For instance, in a population of 156,000 there died 123 from zymotic maladies; required the zymotic rate: $\frac{123 \times 1{,}000}{156{,}000} = 0{\cdot}78$.

(11) *Proportion of Deaths from certain Classes of Disease to the Total Deaths.*

This is a very frequent method of tabulating deaths, and in

sub-districts in which the age-distribution is fairly equal, affords a good basis of comparison.

The calculation is simple ; the deaths from any class are multiplied by 1,000, and divided by the total deaths. The annexed table is an example of the classes usually selected. Taking the first column, to show its construction, the total deaths were 3,087, the zymotic deaths 381, then $\frac{381 \times 1,000}{3,087} = 123$, which are the first figures in column 1.

The deaths from pulmonary complaints were 763, then $\frac{763 \times 1,000}{3,087} = 247$, which are the second figures in column 1, and so on with the other numbers.

TABLE V.

GIVING THE COMPARATIVE MORTALITY OF THE SIX REGISTRATION DISTRICTS FROM CERTAIN CLASSES OF DISEASE, IN PROPORTION TO A THOUSAND DEATHS FROM ALL CAUSES.

	The whole District.	All Souls.	Cavendish Square.	Rectory.	St. Mary.	Christ Church.	St. John.
1. Chief Zymotic Diseases . .	123	109	72	102	130	157	143
2. Pulmonary, other than Phthisis	247	278	230	227	231	264	245
3. Tubercular . . .	137	150	114	136	158	159	108
4. Wasting Diseases of Infancy . .	67	67	48	47	63	73	47
5. Convulsive Diseases of Infancy	58	47	60	80	38	66	63

NOTES.

1, includes Smallpox, Measles, Scarlet Fever, Diphtheria, Whooping Cough, Erysipelas, Croup, Fever, and Diarrhœa.
3, includes Phthisis, Scrofula, Rickets, and Tabes.
4, includes Marasmus, Atrophy, Debility, want of Breast Milk, and Premature Birth.
5, includes Hydrocephalus, Infantile Meningitis, Convulsions, and Teething.

(12) *Proportional Distribution of Deaths.*

In many instances it is impossible to locate the deaths which occur in workhouses and similar institutions, no exact address being discoverable, and in these cases in getting out the death-

rates of sub-districts it is necessary to distribute the deaths according to the population. As this necessitates each time much calculation, it is more convenient to draw out once for all a table, the first line of which gives a factor obtained by dividing the population of the sub-district by the total population, in the second line this factor is multiplied by 2, in the third line by 3, and so on, up to 9. An example of this kind of table will make the system clear.

In the author's district there are the following population groups:—

	Population in 1887.
All Souls	26,759
Cavendish Square	14,891
Rectory	24,809
St. Mary	21,518
Christ Church	34,680
St. John	33,633
TOTAL	156,290

and the proportional table has been constructed by dividing each sub-district by the total population to give the first factor; *e.g.*, by dividing the population of All Souls by the total population, $\frac{26,759}{156,290} = 0{\cdot}17$, which, multiplied by 1, 2, 3, &c., gives the numbers in the first column of the table; in the second a similar process has been adopted for Cavendish Square, thus the population of Cavendish Square, divided by the total population of the district gives the factor ·09, and the same principle has been adopted with the other columns.

TABLE VI.

TO FACILITATE THE DISTRIBUTION OF DEATHS OF PERSONS WHOSE EXACT ADDRESS IS NOT KNOWN.

	All Souls.	Cavendish Square.	Rectory.	St. Mary.	Christ Church.	St. John.
1	·17	·09	·17	·14	·22	·21
2	·34	·18	·34	·28	·44	·42
3	·51	·27	·51	·42	·66	·63
4	·68	·36	·68	·56	·88	·84
5	·85	·45	·85	·70	1·10	1·05
6	1·02	·54	1·02	·84	1·32	1·26
7	1·19	·63	1·19	·98	1·54	1·47
8	1·36	·72	1·36	1·12	1·76	1·68
9	1·53	·81	1·53	1·26	1·98	1·89

The table is used in the following manner. Supposing there are 124 deaths to be distributed between the six sub-districts in proportion to their population; the number for All Souls for 100 deaths will of course be 17 (obtained from the first column by removing the decimal point), 20 will be 3·4, and for 4 the number will be 0·68.

$$\begin{aligned} 100 &= 17 \\ 20 &= 3{\cdot}4 \\ 4 &= 0{\cdot}68 \\ &\overline{21{\cdot}08} \end{aligned}$$

For Cavendish Square the numbers will be $9 + 1{\cdot}8 + 0{\cdot}36 = 11{\cdot}16$; for the Rectory the numbers will be $17 + 3{\cdot}4 + 0{\cdot}68 = 21{\cdot}08$; for St. Mary the numbers will be $14 + 2{\cdot}8 + 0{\cdot}56 = 17{\cdot}36$; the numbers for Christ Church will be $22 + 4{\cdot}4 + 0{\cdot}88 = 27{\cdot}28$; the numbers for St. John will be $21 + 4{\cdot}2 + 0{\cdot}84 = 26{\cdot}04$; and adding these numbers together they will be found to exactly make 124.

E.g.,	All Souls	21·08
	Cavendish Square	11·16
	Rectory	21·08
	St. Mary	17·36
	Christ Church	27·28
	St. John	26·04
		124·00

and by adding the numbers to the deaths of the sub-districts, 124 will have been divided up proportional to the population.

CHAPTER II.

MEAN AGE AT DEATH—MEAN DURATION OF LIFE—PROBABLE DURATION OF LIFE—CONSTRUCTION OF LIFE TABLES.

(13) *Mean Age at Death.*

THE mean age at death of a population is obtained by summing up the ages at which people have died and dividing the number of years by the number of deaths. It is merely an expression of the average at death of a population, and gives no evidence of the health or sanitary condition of the population. When a population is rapidly increasing by excess of births over deaths, the mean age at death is low, because the population is largely composed of young persons. When a population is stationary or nearly so, the proportion of old people to the total population is large, and the mean age at death is high. The mean age at death therefore gives information as to the ages of the dying, and *per contra* of the living, in different communities, but nothing more.

The *mean duration of life* (*mean after-lifetime* or *expectation of life at birth*) differs widely from the mean age at death, when the population is increasing; although when the population is stationary, they coincide. Thus the mean duration of life in England from 1871 to 1880 for males was 41·35 years; if the population had been stationary, the mean age of males who died would also have been 41·35 years, and one in 41·35 would have died annually. Whereas the mean age at death was 29 years, whilst one in 44·2 died annually. One in 44·2 died annually and not one in 41·35, because the increase of population has been so long continued by excess of births over deaths, that an excess of persons between the ages of 5 and 55 has accumulated, whose

mortality is low, and this excess, together with proportional diminution of persons over 55, has served to reduce the death-rate and the mean age of the dying. The mean duration of life is found from life tables, which show how many of a given number born live through each year of subsequent life, and what is the sum of the number of years they live. The sum of these years divided by the lives is the mean duration of life.[1] "It is the mean lifetime of a generation of persons traced by the life-table method from birth to death."—*Noel Humphreys.*

There is no accurate method known to calculate mean duration of life, save from life tables, although the following methods are sometimes used:—

(14) *Calculation of Mean Duration of Life.*

The mean duration of life may be approximately calculated from the birth-rate and death-rate by the following formula:—Mean duration of life $= \left(\frac{2}{3} \times \frac{1}{d}\right) + \left(\frac{1}{3} \times \frac{1}{b}\right)$, where $b =$ birth-rate per unit of population; and $d =$ death-rate per unit of population.

For example, given a birth-rate of 35·35, a death-rate of 21·27 per thousand; required the mean duration of life.

$$\left\{\frac{2}{3} \times \frac{1}{\cdot 02127}\right\} + \left\{\frac{1}{3} \times \frac{1}{\cdot 03535}\right\} = \cdot 04076, \text{ or } 40\cdot 76 \text{ per } 1000.$$

What is known as Bristowe's formula is also sometimes used.[2]

(15) *The Probable Duration of Life.*

The probable duration of life is the age at which a given number of children born at the same time are reduced one-half, it is therefore not the same as the "mean duration of life."

[1] Dr. Louis Parkes, "Some Aspects of Mortality Statistics," *Public Health*, No. 4, 1888.

[2] Bristowe's formula is as follows:—

x = mean duration of life.
b = birth-rate of one unit of the population.
d = death-rate of one unit of the population.
$r = b - d$ = increase of one unit in one year.

Then—

$$x = \frac{\log b - \log d}{\log (1 + r)}.$$

(16) *Construction of Life Tables.*

Life tables are calculated on a hypothetical generation of a million persons, consisting of the same proportion of males and females at birth and at subsequent ages which is found to exist in the general population, and on the numbers of each sex dying each succeeding year, until the whole generation becomes extinct.

The expectation of life or mean after-lifetime of various ages, represents the portion of future life which an individual at any age may reasonably expect to enjoy; and this, like the mean age at death or mean duration of life, is given in life tables. The following is Mr. Noel Humphrey's short table showing clearly how the recent decline in the English death-rate has affected the mean after-lifetime at various ages:—

Table VII.

Showing Mean After-Lifetime (Expectation of Life) at Various Ages, from Life Tables based upon English Mortality in 1838—54 (*N. Humphreys*).

	Persons.		Males.		Females.	
Ages.	1838—54.	1876—80.	1838—54.	1876—80.	1838—54.	1876—80.
0	40·86	43·56	39·91	41·92	41·85	45·25
5	50·02	52·56	49·71	51·47	50·33	53·65
10	47·36	49·24	47·05	48·16	47·67	50·32
15	43·54	45·05	43·18	43·94	43·90	46·15
20	39·88	40·98	39·48	39·86	40·29	42·10
25	36·57	37·21	36·12	36·05	37·04	38·36
35	29·99	30·01	29·40	28·88	30·59	31·12
45	23·41	23·29	22·76	22·34	24·06	24·21
55	16·94	16·75	16·45	16·09	17·43	17·37
65	11·17	11·19	10·82	10·79	11·51	11·55
75	6·72	6·81	6·49	6·52	6 93	7·04
85 and upwards . .	3·87	4·00	3·73	3·78	3·98	4·15

The life table is an instrument of investigation; it may be called a biometer, for it gives the exact measure of the duration of life under given circumstances. Such a table has to be constructed for each district and for each profession to determine their degrees of salubrity, which while they involve a minimum amount of arithmetical labour will yield results as correct as can be obtained in the present state of our observations.

A life table represents a generation of men passing through time; and time under this aspect, dating from birth, is called age. In the first column of a life table, age is expressed in years, commencing at 0 (birth) and proceeding to 100 or 110 years, the extreme limit of observed lifetime.

If we could trace a given number of children, say 100,000, from the date of birth, and write the numbers down that die in the first year, living therefore less than one year, against 0 in the table, and on succeeding lines the numbers that die in the second, third, and every subsequent year of age until the whole generation had passed away, these numbers would form a table of mortality, showing at what ages 100,000 lives become extinct.

Again if the 100,000 children were followed, and the numbers living on the first, on the second, and on every subsequent birthday until none were left, the column of numbers would constitute a *table of survivorship.* So if of 100,000 children born at a given point of time, the numbers dying (d_x, see Life Table, p. 33) in each subsequent year were written in one column, and the numbers surviving (l_x) at the end of each year in another column, the two primary columns of the life table would be formed.

It is evident that if one of these columns is known the other may be immediately deduced from it; for if, of 100,000 children, 10,295 die in the first year of age, 3,005 in the second year of age, it follows that the numbers living at the end of one year must be 89,705, at the end of two years 86,700. Upon adding the column (d_x) from the bottom up to the number against any age (x) the sum will represent the whole of the numbers *dying after that age;* and consequently the numbers living at that age, as shown in the collateral column (l_x).

The 100,000 children born at the same moment, and counted annually to determine the numbers living at the end of every year, would by our table completely pass away in less than 107 years. If another generation of 100,000 born a year afterwards were followed, the numbers dying in various years of age would not be very different, the circumstances remaining the same; and the number of those entering each year of age would vary inconsiderably from those of the first series. If 100,000 children again were born at annual intervals, and were subject to an invariable law of mortality, they would form a community of which the numbers

living at each age would be represented by the successive numbers (l) in the life table. The sum of these numbers, by Dr. Farr's life table No. 3, for healthy districts, would be 4,951,908. The births are here assumed to take place simultaneously at annual intervals; immediately before the births, therefore, in such a community its population would be 4,851,908, to which it would fall progressively from 4,951,908 by 100,000 successive deaths in the year. The average number constantly living would be some number between 4,951,908 and 4,851,908; and it would be very nearly the mean of these limiting numbers.

In the ordinary course of nature, the births take place in remittent succession; and if it is assumed that the 100,000 births occur at equal intervals over every year, it is evident that at any given date a certain number will be found living at all the intermediate points of age between 0 to 1 year, 1 to 2, 2 to 3, and all the remaining years of age; the population in the above instance would be found by enumeration to be nearly 4,899,665.

The annual births would be 100,000 in such a community. The annual deaths would also be 100,000, and by taking out the deaths at each year of age, from the parish registers of a single year, the second column (d_x) of the life table would be found. By adding this column of deaths up, and entering the sum of the numbers year by year against each year of age (x), the third column (l_x) of the life table would be obtained, for it has been already shown that the numbers attaining any age (x) are equal to the numbers dying at that age and all subsequent ages. From the registers of the deaths, a table of the numbers of the population living, in a parish so constituted, could be immediately determined without any enumeration. Its deviations from the truth would be accidental, and they would be set right by taking the mean of many years. So also from a simultaneous enumeration of the numbers living in each year of age, the two columns d_x and l_x of the life table could be constructed without reference to any registry of the deaths at different ages.

The mean age at death in such a community would express the *mean lifetime*, or the *expectation of life* at birth; and the product of the number expressing the annual births into the mean age at death would give the numbers of the population. The deaths in each year of age are called the *decrement of life*. The decrement in the first year is large; in the first five years the decrements of

life are considerable; at the age of 10–15 they fall to their minimum; slowly increase to the age of 56; increase more rapidly until the maximum is attained at the age of 75; then decline gradually to 85, and after that more rapidly until every life is extinct at the age of 107 by this table.[1]

(17) *Construction of Short Life Tables.*

According to De Moivre's hypothesis the numbers living decrease in an arithmetical progression down to nothing at the age of 86; it has since been assumed that the number living in any year of their age is an arithmetical mean proportional between the numbers that annually enter upon and that annually complete that year. If *d* deaths occur in a year, they are assumed to take place at *d* equal intervals; and it is by the same hypothesis that, in calculating the expectation of life, it is assumed that the number of living of the age of *n* years and upwards is less than the sum of those that annually complete that and all the greater ages by half the number that annually complete that year of their age. The errors involved in the hypothesis of an equal decrement are greatest in the first year of life; but by making the births the basis of the table (if the births are all registered), the decrement in the first year will be correctly represented—in other words, the hypothesis is not to be applied to the first year; *e.g.* if the deaths in the second year of life were 6·503 out of a hundred constantly living, by the hypothesis 1·03252 would be alive at the beginning, and 0·96748 at the end, of the second year; the fraction $\frac{96{,}748}{103{,}252}$ would therefore express the chance of living the second year. If 43,104 were alive at the beginning, 40,388 would be alive at the end, of the second year. For 103,252 : 96,748 :: 43,104 : 40,388; or $\frac{96{,}748}{103{,}252} \times 43{,}104 = 40{,}388$. In this manner the series down to 5 years may be calculated (Farr).

By the above method, in the construction of Dr. Farr's short Surrey life table,[2] it was found that out of 50,521 boys born in

[1] Dr. Farr, "On the Construction of Life Tables, illustrated by a new Life Table of the Healthy Districts of England," *Trans. of Roy. Soc.*, 1859, pp. 832–841.
[2] Dr. Farr, *Fifth Annual Report*, "Vital Statistics," by Wm. Farr, ed. by Noel A. Humphreys, p. 467.

Surrey, 43,637 live a year, 41,857 two years, 40,704 three years, 40,031 four years, 39,550 five years.

The next point was to determine how many of the 39,550 attain the age of ten years. The living enumerated at the age of 5–10 were 13,588, the deaths 145; and after the proper correction the mortality, m, was ascertained to be 0·01050; so $\frac{m}{2} = 0·00525$, and $\frac{1 - \frac{1}{2}m}{1 + \frac{1}{2}m} = \frac{·99475}{1·00525} = ·98955$, the probability of living one year at the middle of the period, or at $7\frac{1}{2}$ years of age. But it may be assumed that $\left(\frac{1 - \frac{1}{2}m}{1 + \frac{1}{2}m}\right)^5 = p_{5·5}$ = the probability of living five years from the age of 5 to 10, and $(0·98955)^5 = 0·94885$, which $\times$ 39,550 gives 37,527 = the numbers surviving at the age of 10.

If the calculation be continued down to 15, 20, 25, and every fifth year to the end, the following table will be obtained :—

TABLE VIII.

SURREY LIFE TABLE : MALES (1841).

Age.	Living.	Quinquennial Periods + ½ l.m.
0	50,521	476,444
1	43,637	
2	41,857	
3	40,704	
4	40,031	
5	39,550	425,923
10	37,527	386,373
15	36,469	348,846
20	35,338	312,377
25	34,061	277,039
30	32,742	242,978
35	31,189	210,236
40	29,822	179,047
45	28,069	149,225
50	25,973	121,156
55	23,892	95,183
60	21,459	
65	18,235	
70	13,976	
75	9,836	
80	5,393	
85	2,031	
90	290	
95	58	
100	11	
105	2	

Add up the column headed (living) to the number 39,550 (against the age of 5 years) and the sum will be the number of 5 years—of *lustres*—which the 39,550 persons will live $+ \frac{39,550}{2} = 19,775$. Subtract, therefore, 19,775 from the sum 425,923, and 406,148 will remain, which, divided by 39,550, gives for quotient 10·2691 lustres as the expectation of life at that age. A lustre is five years, consequently the expectation of life is five times 10·269 or 51·3 years. If 425,923 be divided by 39,550 the quotient will be 10·769, and $10{\cdot}769 - 0{\cdot}5 = 10{\cdot}269$, the same result as before. The expectation of life will be found to be 34·5 at the age of thirty.

The number of living at every five years, except the first deduced by this method, may be considered nearly correct; the expectation of life is slightly overstated by the assumption that the living at ages 5, 6, 7, 8, 9, 10, and 10, 11, &c., are series in arithmetical progression. The error does not exceed one-tenth part of a year from 5 to 60 years of age. At birth and after 70 it does not exceed half a year, which may be subtracted as a correction. But by calculating the numbers surviving every year up to the age of 5, a sufficiently close approximation to the expectation of life at birth will be obtained. The years of life under 5 are $\frac{5}{6} \times 256,300 = 213,583$; and the years of life, after the age of $5 = 5 \times (425,923 - 19,775) = 2,030,740$, and $\frac{2,030,740 + 213,583}{50,521} =$ 44·4, a boy's expectation of life in Surrey.

A life table still shorter may be constructed by taking intervals of ten years, and using $\left(\frac{1 - \frac{1}{2}m}{1 + \frac{1}{2}m}\right)^{10}$. The errors in the calculation of the expectation of life from the living at every tenth year can be corrected. They are always of the same nature. If we take the numbers "living" against every tenth year from the English table, it will be found that the excess of the expectation of life ranges at the ages 10–50 from 0·1 to 0·2 or 0·3 of a year. At birth the true expectation will be obtained very nearly by subtracting one year from the expectation derived from the decennial table.

By adding up the column headed "living" in the subjoined

table, dividing by the first number 100,000, multiplying by 10, and subtracting 5, we obtain 42·05 years as the expectation of life, which is too much by ·9 of a year.

$$\text{Age } 0.\quad \frac{470{,}530}{100{,}000} \times 10 = 47{\cdot}05\,;\ \text{and } 47{\cdot}05 - 5 = 42{\cdot}05 \text{ years.}$$

True expectation of life 41·16

Error 0·89

$$\text{Age } 10.\quad \frac{370{,}530}{70{,}612} \times 10 = 52{\cdot}47\,;\ \text{and } 52{\cdot}47 - 5 = 47{\cdot}47 \text{ years.}$$

True expectation of life 47·44

Error 0·03

TABLE IX.

DECENNIAL LIFE TABLE (*from the English Table*).

Years.	Living.	Expectation of Life.		
		By the decennial table.	Error.	By the annual table.
0	100,000	42·05 . . .	·89 =	41·16
10	70,612	47·47 . . .	·03 =	47·44
20	66,059	40·40 . . .	·06 =	40·34
30	60,332	33·76 . . .	·08 =	33·68
40	53,825	27·23 . . .	·09 =	27·14
50	46,621	20·67 . . .	·12 =	20·55
60	37,996	14·23 . . .	·23 =	14·00
70	24,531	9·29 . . .	·51 =	8·78
80	9,398			
90	1,140			
100	16			

(18) *The Construction of an Extended Life Table.*

An excellent and practical description of the construction of an extended life table was published in the *Journal of the Statistical Society*, vol. xlvi. pp. 189–213, by Mr. Noel A. Humphreys, for the avowed purpose of enabling those who had no very profound knowledge of mathematics to construct similar tables, as well as to show the influence of the decrease in mortality on the expectation of life. As it is impossible to state the substance of the paper in more concise or clearer language, the description is here quoted verbatim, and illustrated by printing a portion of the life table for males :—

"To start with, there is a hypothetical million of persons ; 509,208 are assumed to be males, and 490,792 females.

"The first process was to ascertain the mean annual death-rate in the seventeen years 1838–54, and in the five years 1876–80, at each of the twelve groups of ages dealt with by the Registrar-General in his annual reports; then to calculate the rate of increase or decrease between the relative rates prevailing in these two periods at each group of ages. These results are shown in Table X.

TABLE X.

MEAN ANNUAL MORTALITY OF MALES AND FEMALES IN ENGLAND AND WALES IN SEVENTEEN YEARS 1838—54, AND IN FIVE YEARS 1876—80.

Groups of Ages.	Males. Mean Annual Death-rate per 1,000 living. 1838—54.	Males. Mean Annual Death-rate per 1,000 living. 1876—80.	Males. Increase or Decrease per cent.	Females. Mean Annual Death-rate per 1,000 living. 1838—54.	Females. Mean Annual Death-rate per 1,000 living. 1876—80.	Females. Increase or Decrease per cent.
All ages	23·25	22·16	− 4·676	21·64	19·54	− 9·685
0— 5	72·25	67·20	− 6·986	62·13	57·02	− 8·224
5—10	9·19	6·44	− 29·955	8·93	5·98	− 33·030
10—15	5·16	3·50	− 32·155	5·49	3·56	− 35·203
15—20	7·11	4·96	− 30·199	7·95	5·14	− 35·322
20—25	9·46	6·84	− 27·732	9·05	6·30	− 30·364
25—35	12·86	8·70	− 12·949	10·49	7·94	− 24·296
35—45	9·99	13·48	+ 4·783	12·79	11·22	− 12·303
45—55	18·29	18·96	+ 3·640	15·96	14·94	− 6·384
55—65	31·74	34·64	+ 9·133	28·16	28·26	+ 2·469
65—75	66·80	67·60	+ 1·198	59·82	60·16	+ 0·562
75—85	147·36	146·72	− 0·434	134·46	132·26	− 1·635
85 and upwards	308·21	304·08	− 1·339	288·16	273·98	− 4·922

"Then, starting with the annual mortality of males in each *year of age*, according to Dr. Farr's English life table No. 3, these rates [see col. 1 of T. XI.] are reduced or raised in accordance with the relation between the mean mortality that prevailed in the several *groups of ages* in 1838–54, and in 1876–80 respectively. For instance, it is shown in Table X. that at the first group of ages (0–5), the mean annual death-rate of males declined from 72·25 per cent. in 1838–54 to 67·20 in 1876–80, equal to a decrease of 6·986 per cent. It has been assumed that the rate of mortality in each of the first five years of age, as shown in Dr. Farr's Table, had declined in the same proportion as the rate for the entire group of

five years. Each of the first five rates in col. 1 was therefore multiplied by ·93014, reducing each of them by 6·986 per cent., and thus constituting the 'corrected rate of mortality' for each of the first five years of age appearing in col. 2 of Table XI. The yearly rates in each group of ages were dealt with in a similar manner, the rates for the five years 5–10 being reduced 29·955 per cent.; those for the five years 10–15, 32·155 per cent.; and so on through each of the twelve groups of ages. These corrected rates of mortality at each year of age constitute the m_x of the new life table. There is an obvious defect in this series of corrected annual rates of mortality, viz. the irregularities due to the assumption that the changes in the proportions of decrease in the mean rates of succeeding age-periods, took place suddenly at the commencement of each period, instead of coming gradually into operation, as was certainly the case. The series would undoubtedly look better, and would probably be more technically correct, if these irregularities had been graduated and smoothed away, but having regard to the intended purpose of the table, this process has been omitted.

"From this mortality (m_x) column the probability of living at each year of age (p_x) has been obtained by the formula $p_x = \frac{2 - m_x}{2 + m_x}$. Thus $\frac{2 - \cdot17046}{2\cdot17046} = \cdot84293$, which represents the corrected probability of a male living one year from birth.

"By this process, the probability of living one year is obtained for each age in the series.

"The next column required is one showing the numbers born and living at each age (l_x). We start for reasons that have already been described, with 509,208 males at birth, and having ascertained the probability at birth of living one year to be ·84293, the survivors attaining one year of age or (l_1) may be obtained by multiplying 509,208 by ·84293. Carrying on this process of multiplying the numbers surviving to each year of age by the probability at that age of living one year, the survivors to the next age are successively obtained, until the generation becomes extinct.

"Thus the formula used for obtaining the l_x column is :—($l_x \times p_x = l_{x+1}$). This process, laborious by common arithmetic, is shortened by the use of logarithms. By adding the logarithm of p_0 to the logarithm of l_0, the logarithm of l_1, or the number calculated to

complete the first year of life, is obtained. The addition of the logarithm of p_1 to the logarithm of l_1 in like manner gives the logarithm of l_2, and so on to the end of the series.

Table XI.

A Portion of Mr. Noel Humphrey's English Life Table, based on Mortality in Five Years 1876—80 : Males.

Cols.	1	2	3	4	5	6
x	m_x = Annual Mortality at each year of life. English Life Table.	Corrected for years 1876—80.	p_x = Probability of living one year from each age.	l_x = Numbers born and living at each age.	P_x = Mean numbers living in each year of age.	q_x Years which the males at each age will live.
0	·18326	·17046	·84293	509,208	469,218	21,347,889
1	·06680	·06213	·93974	429,227	416,294	20,878,671
2	·03624	·03371	·96685	403,361	396,675	20,462,377
3	·02416	·02247	·97778	389,990	385,657	20,065,702
4	·01799	·01673	·98341	381,324	378,161	19,680,045
5	·01369	·00959	·99046	374,998	373,210	19,301,884
6	·01088	·00762	·99241	371,421	370,011	18,928,674
7	·00920	·00644	·99358	368,602	367,419	18,558,663
8	·00767	·00537	·99464	366,235	365,253	18,191,244
9	·00649	·00455	·99546	364,272	363,445	17,825,991
10	·00563	·00382	·99619	362,618	361,928	17,462,546
11	·00507	·00344	·99657	361,237	360,617	17,100,618
12	·00478	·00324	·99677	359,998	359,417	16,740,001
13	·00472	·00320	·99681	358,835	358,262	16,380,584
14	·00486	·00330	·99671	357,690	357,102	16,022,322
15	·00519	·00362	·99639	356,513	355,869	15,665,220
16	·00564	·00394	·99607	355,226	354,528	15,309,351
17	·00622	·00434	·99567	353,830	353,064	14,954,823
18	·00688	·00480	·99521	352,298	351,455	14,601,759
19	·00759	·00530	·99471	350,611	349,683	14,250,304
20	·00832	·00601	·99401	348,756	347,712	13,900,621
21	·00850	·00614	·99388	346,667	345,606	13,552,909
22	·00868	·00627	·99375	344,546	343,469	13,807,303
23	·00886	·00640	·99362	342,392	341,300	12,863,834
24	·00903	·00653	·99349	340,208	339,101	12,522,534
25	·00920	·00801	·99202	337,993	336,644	12,183,433
*	*	*	*	*	*	*
96	·44444	·43849	·64036	565	403	
97	·47312	·46678	·62155	362	294	718
98	·50000	·49331	·60429	225	180	424
99	·53398	·52683	·58301	136	108	244
100	·55000	·54264	·57317	79	62	136[1]

[1] This number shows how many years the 79 males who attain the age of 100 years will live, calculated by the English Life Table No. 3.

"The next necessary column for our purpose is one showing the mean numbers living *in* each year of age, which is obviously less than the number surviving *to*, or living *at the commencement of each year*. This column is described in a life table as P_x, meaning the mean population living during the year following each age in the series. It is assumed that the number living in each year of age is the arithmetical mean of the numbers living at the beginning and at the end of the year. P_x is therefore equal to $\frac{l_x + l_x + 1}{2}$. This also indicates the number of years of life lived in the year, from age x to age $x + 1$.

"The last column given in the table is what is technically called the q_x column. The number against any age in this column is the sum of all the numbers in the P_x from that age to the end of the table. It therefore shows the aggregate number of years which the males at each age in the table will live, until their extinction by death. Thus q_0 is equal to 21,347,889, showing that according to this life table the generation of 509,208 male infants at birth, which was assumed as the radix of the male table, would live this aggregate number of years before final extinction by death; and $\frac{q_x}{l_x}$ gives the mean future lifetime of all the persons living at age x in the table, and as $\frac{21,347,889}{509,208} = 41{\cdot}92$, the mean duration of life of a generation of males subject to the mean rates of mortality that prevailed at twelve groups of ages during the five years 1876–80 would be 41·92 years."

CHAPTER III.

AIDS TO CALCULATION.

(19) *Tables.*

First in order are suitable tables, *e.g.*, logarithms to four or five figures; of these Mr. Hy. Law's and Dr. C. J. Woodward's will be found most convenient. Hoüel's reprint of Lalande is also to be commended. Crelles' multiplication tables, by the aid of which three figures may be dealt with at once, and reciprocals such as Lieut.-Col. Oakes's tables (footnote, p. 15) which reduce division to the short multiplication of decimals and render easy the addition of fractions are all useful.

The greatest saving in labour and avoidance of monotony is however obtained from the use of mechanical aids such as Professor Fuller's Spiral Rule and the Arithmometer

(20) *Professor Fuller's Spiral Rule.*[1]

The rule (Figs. 1 and 2) consists of a cylinder jacket (d) that can be moved up and down upon, and turned round, an axis (f), which is held by a handle (e). Upon this cylinder is wound in a spiral a single logarithmic scale. Fixed to the handle is an index (b) which for distinction may be called "the indicator," for the answer to a sum is always read from it. Two other indices (c) and (a), whose distance apart is the axial length of the complete spiral, are fixed to the cylinder (g). This cylinder slides in (f) like a telescope tube, and thus enables the operator to place these indices on any part of the scale. Two stops (o) and (p)

[1] Messrs. Stanley, Great Turnstile, are the agents. The price is 3*l.*

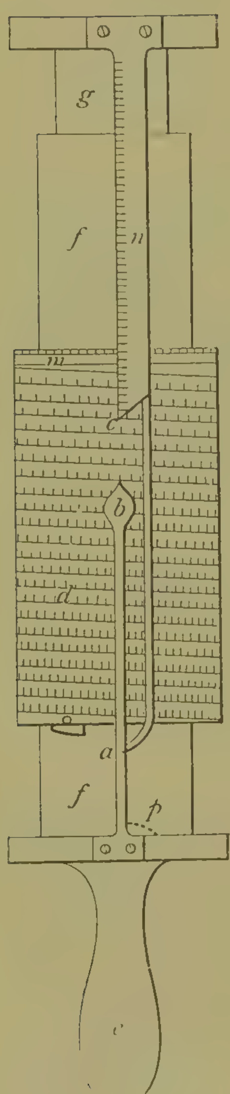

FIG. 1.

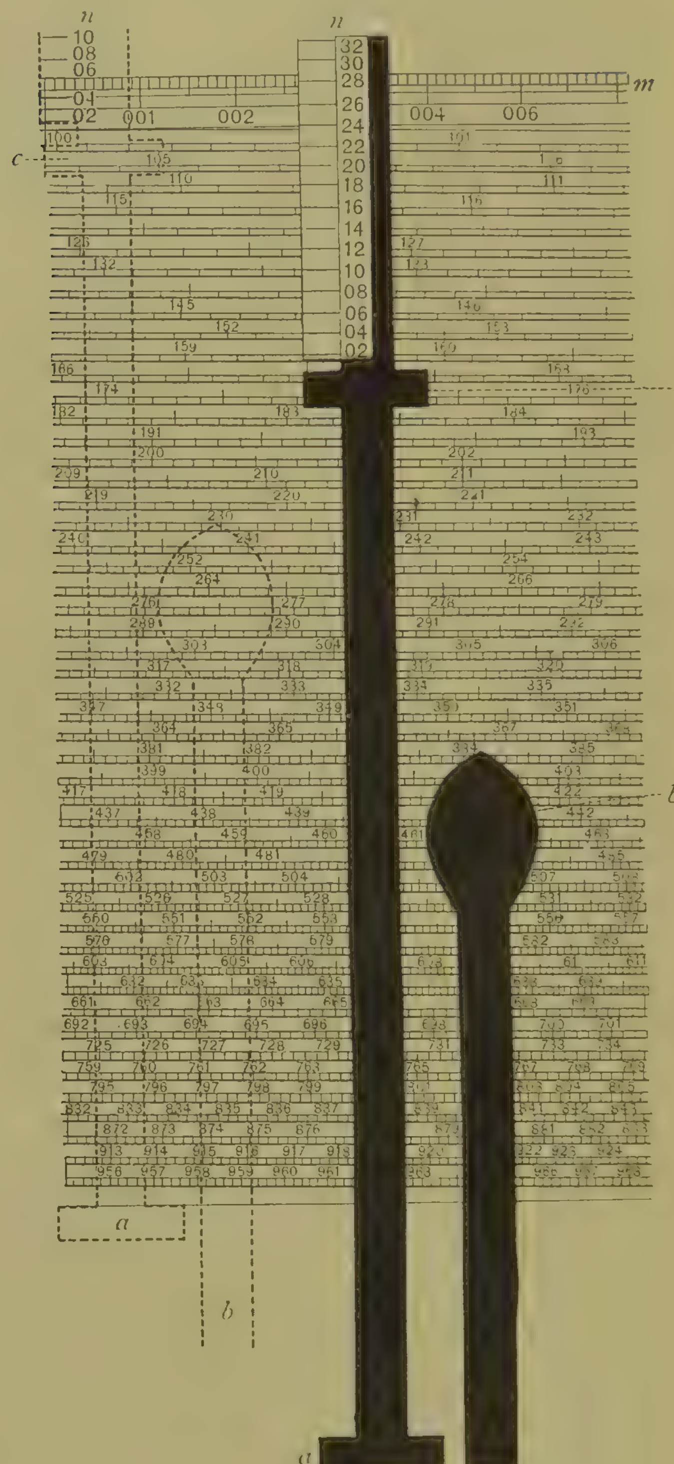

FIG. 2.

are so fixed that when they are brought in contact, the index (*b*) points to the commencement of the scale. (*n*) and (*m*) are

two scales, the one on the piece carrying the movable indices, the other on the cylinder (d).

The scale commences with 100 and ends with 999, the hundred is read either as one, or ten or a hundred, or a thousand, as may be required; all the others are read in a similar manner thus: 827 is 8·27, or 82·7, or 827000.

(21) *Multiplication by the Spiral Rule.*

The two main arithmetical operations, multiplication and division, will be readily understood by reference to the diagram which gives a portion of the scale and the indices. The indices it will be noticed are of a different shape to that of the previous figure, the reason being that Fig. 1 represents Professor Fuller's original idea, and the diagram (Fig. 2) the latest form of index, the brass, slip carrying the indices a and c and the logarithmic scale n, having the advantage that if it happens that the edge of the index cannot be seen from being under the indicator instead of the left edge being used for reading the right edge can be used.

Supposing we multiply by the aid of the instrument 230 by 167, place the indicator b as shown by the dotted line at 230, the upper index c in the position shown in the diagram dotted line at 100 that is zero, now turn the cylinder (*not the indices*) until 167 is as shown by the blackened figure at 167, then the indicator b points to 3841. The rule for the number of figures in the product is the algebraic sum of the number of figures in the factors, minus one for each factor brought to the upper index c, the number of figures in the factors 230 and 167 is six, but 167 has been brought to the upper index, and therefore 1 must be subtracted; hence the answer is 5 figures, and the product of multiplying 230 by 167 is 38,410.

(22) *Division by the Spiral Rule.*

The same diagram may be used for the purpose of explaining division. Supposing we wish to prove the above multiplication to be correct, if it is so, then dividing 38410 by 167 should give 230. Place the indicator b as shown *black*, pointing to 3841, place the upper index c as shown *black* at 167, then turn the cylinder round until the index c is at zero, the indicator will now point to 230 thus giving the answer. To know the number of figures in a quotient, the rule is to take the algebraic difference

between the number of figures in the divisor and dividend and add one each time the upper index c is used. In this case the algebraic difference between the factors 3-5 = 2 the upper, not the lower, index has been used; we must therefore add 1, the quotient must therefore consist of three figures only, hence we know the answer is not 2·3 or 2,300, or any other figure but 230.

The following examples are taken from Professor Fuller's paper of instructions.

EXAMPLES.

MULTIPLICATION.—48·42 × ·06434 = 3·1153. In this case 6434 is brought to a, so that the number of figures in the product is the sum $2 + (-1) = 1$.

13·28 × 142·7 = 1894·9. In this case 142 is brought to c, so that the number of figures in the product is the sum $-1 = 5 - 1 = 4$.

What is the weight of a bar of iron 14 ft. × 3″ × 2″; weight of a cubic inch of iron ·277 lbs.?

14 × 12 × 3 × 2 × ·277 = 279·21 lbs. In this case three of the factors have to be brought to c, so that the number of figures in the product $= 6 - 3 = 3$.

DIVISION.—486·34÷·0723=6726·5. In this case a is set to 723, so that the number of figures in the quotient is
Difference $+1-1=3-(-1)+1-1=4$.

·01368÷12·64=·001082. In this case c is set to 1264, so that the number of figures in the quotient is
Difference $+1=-1-2+1=-2$.

How many gallons will a cistern 4·75′ × 3·5′ × 2·75′ hold; a gallon is ·16037 cub. ft.?

$$\frac{4·75 \times 3·5 \times 2·75}{·16037} = 285·08.$$ The Difference $+1=4$, but c is set to 275, so that the number of figures in the quotient $=4-1=3$.

A stone 21·75″ × 15·25″ × 8⅓″ weighs 268¾ lbs. How many cubic feet are there in 238 tons?

$$\frac{21·75 \times 15·25 \times 8·333 \times 238 \times 2240}{268·75 \times 1728.} = 3172·8.$$ Difference $+2=7$, but a is set to 26875 and 1728, and 224 is brought to c, so the number of figures in the quotient $=7-3=4$.

If 48 men working 8 hours a day for 7 days can dig a trench 235′ × 40′ × 28′; in how many days can 12 men working 10 hours a day dig 156,060 cub. yds.?

Here
$$\begin{array}{c} 12 : 48 :: 7 : x \\ 10 : 8 \\ \dfrac{235 \times 40 \times 28}{27} : 156,060 \end{array}$$

$$\frac{7 \times 48 \times 8 \times 156060 \times 27}{12 \times 10 \times 235 \times 40 \times 28} = 358·6$$

Difference $+5=12-11+5=6$.

But 15606 is brought to c, and a is set to 40 and 28, so the number of figures in the quotient $=6-3=3$.

These examples show that the rule gives very great facility for obtaining numerical results; also that the results are a sufficient approximation for most practical purposes.

RATIO.

When either of the movable indices is at one number and the indicator at another, and the cylinder is turned into any other position, though the numbers at the indices will be different, their ratio will remain constant.

EXAMPLE.—To convert francs and centimes into sterling money, supposing exchange 25f. 45c. for 1*l.* The ratio between centimes and pence is 2545 to 240. Place

the cylinder so that the indicator is at 2545, and make one of the movable indices point to 240. Then on moving the cylinder to read off different numbers of centimes at the indicator, the corresponding value in pence will be read at the movable index.

WAGES TABLE.—To find the wages for different times at 35*s.* per week of 57 hours. Place the cylinder so that the indicator is at 57, and make one of the movable indices point to 420, the number of pence in 35*s.* Then on moving the cylinder to read off different numbers of hours at the indicator, the corresponding wages in pence will be read at the movable index.

LOGARITHMS, POWERS AND ROOTS.

To obtain powers not higher than the seventh, the quickest way is by direct multiplication.

For higher powers and roots. Place the upper movable index (c) to the number, and read the scales (n and m). (See Fig. 2.) These together give the *mantissa* of the logarithm of the number. To this the *index* has to be added. The index of the logarithm of a number greater than unity is *one less* than the number of figures in the integral part of that number. Thus the index of 5432 is 3, of 543·2 is 2, of 54·32 is 1, and of 5·432 is 0.

Multiply or divide the resulting number by the power or root, as shown above. Then place the cylinder so that it reads on the scales (n and m) the decimal part of the quotient. The power or root is then at the index (c). In the result the number of figures before the decimal point is *one more* than the number in the integral part of the above quotient.

The scale (n) is read from the *lowest line* of the top spiral and (m) from the vertical edge of the scale (n). Thus in the diagram, page 36, (n) reads ·22, (m) reads ·0027. These must be added together making ·2227, which is the mantissa of the logarithm of 167 to which (c) points.

EXAMPLES.—5^{13}, on placing (c) to 500, scale (n) reads ·68 and scale (m) ·01897, which gives the logarithm of 5 – ·69897, the index being 0. Then $·69897 \times 13 = 9·08661$. Now placing the cylinder so that it reads ·08661 on scales (n and m) the index (c) reads 12207, and the required power is 1220700000, having 10 figures, as the integral part of the above quotient is 9.

$\sqrt[5]{741}$ on placing (c) to 741, scale (n) reads ·86 and scale (m) ·00982 which gives the logarithm of 741 – 2·86982, the index being 2. Then $2·86982 \div 5 = ·57396$. Now placing the cylinder so that it reads ·57396 on scales (n and m) the index (c) reads 37495, and the required root is 3·7495, having one figure before the decimal point, as the integral part of the above quotient is 0.

ROOTS OF DECIMAL FRACTIONS.

Write them as vulgar fractions, and multiply numerator and denominator by ten or a power of ten, so that the denominator may have a complete root. Then take the required root of the numerator by the method given above, and of the denominator by inspection :

$$\text{Thus } \sqrt{·4} = \sqrt{\frac{4}{10}} = \sqrt{\frac{40}{10^2}} = \frac{\sqrt{40}}{10}$$

$$\sqrt[3]{·04} = \sqrt[3]{\frac{4}{10^2}} = \sqrt[3]{\frac{40}{10^3}} = \frac{\sqrt[3]{40}}{10}$$

$$\sqrt[5]{·586} = \sqrt[5]{\frac{586}{10^3}} = \sqrt[5]{\frac{58600}{10^5}} = \frac{\sqrt[5]{58600}}{10}$$

$$\sqrt[3]{·00065} = \sqrt[3]{\frac{65}{10^5}} = \sqrt[3]{\frac{650}{10^6}} = \frac{\sqrt[3]{650}}{10^2}$$

$$(·0434)^{\frac{5}{6}} = \left(\frac{434}{10^4}\right)^{\frac{5}{6}} = \left(\frac{43400}{10^6}\right)^{\frac{5}{6}} = \frac{(43400)^{\frac{5}{6}}}{10^5}$$

The facility of obtaining and working with the logarithms of numbers gives the rule a great additional value.

TABLES.

There are tables printed on the rule which have been made and selected as those considered most useful. Owing to our want of a decimal system, it has been deemed most important to have a series of tables which give for our measures of weight, length, time, &c., the equivalent decimal fraction of the larger for successive numbers of the smaller unit. This enables results to be obtained without the necessity of reduction. Thus to find the area of a rectangle whose sides are 24′ 6¼″ and 43′5½″. The table gives by inspection ·5208 and ·4583 opposite 6¼″ and 5½″ respectively, so that the area is obtained by multiplying 24·521 by 43·458. The result, as shown by the rule, is 1065·6. If the parts of a square foot are required in twelfths, the table shows that ·6 of a foot is equivalents to 7¼ twelfths, and the result reads 1065 – 7¼.

ADJUSTMENTS OF INSTRUMENT.

1. When the top movable index points exactly to 100 the bottom movable index must point exactly to the end of the scale.

2. When the top index points exactly to the end of the scale, the beginning of the scale must be just covered by the edge of the brass scale.

There are two pairs of movable indices. When the use of one pair would cause the stem of the indices to interfere with the fixed index, the other pair are to be used.

The adjustment of the index is made by means of one of the screws fastening it to the wood disc.

(23) *The Arithmometer.*

There are at present in the market two species of calculating machines, one a straight instrument, the other a semi-circular. Both are on the same principles, and nearly the same price. It is claimed for the circular known under the name of Edmonson's circular machine, that,

The Driving-handle is in the easiest possible position for the hand and wrist.

The use of a circular instead of a straight slide brings the "product holes" close under the eye of the operator; and, being placed in shallow apertures, all the figures are easily visible.

The Circular form admits of *any* product disc being brought opposite *any* digit on the face-plate, and permits the working of very extended products and quotients. A product of twenty figures can be worked without special management.

Two sets of factors can be worked on to the circle (and without intermediate record), the two results can then be worked together as addends, subtrahend and minuend, multiplicand and multiplier, or dividend and divisor.

Quotients appear in the same line of apertures as products, but on a different part of the circle, *clearly marked off*, and (without transferring) are in a position to be further operated on as addends, minuends, multipliers or dividends; or they can be transferred to

the face-plate, to be worked as subtrahends, multiplicands, or divisors.

The Eraser will bring to zero either the whole or a part of the figures on the circle.

Click-springs to the number discs (a source of constant annoyance) are dispensed with. All the discs are locked (when the circle is in its working position), except when the mechanism requires them to move. Thus great certainty of action is insured.

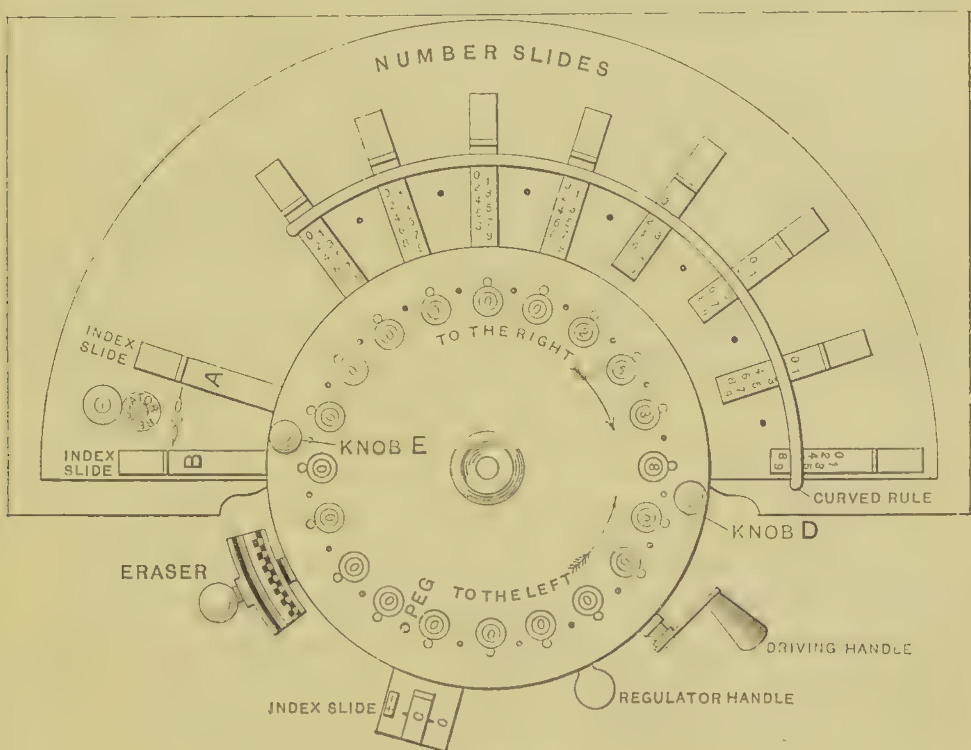

Fig. 3.

The "Markers" on the face-plate have flat thumb-pieces, and can be set as often as desired without hurting the fingers.

Its principle is extremely simple. Beneath each Number Slide are two radial axes, one above the other. The lower one makes one revolution for each revolution of the motive handle, and has upon it a cylinder. That half of the cylinder which is farthest from the centre of the machine is devoted to reckoning; and the other half to stopping and locking the axis above it, until the moment when the reckoning half, or "reckoner," begins to operate. The "reckoner" is again divided into 10 sections, on which there

are respectively 0, 1, 2, 3, 4, 5, 6, 7, 8 and 9 teeth, and a considerable blank space; the section with 9 teeth being the farthest from the centre of the machine. The 8 teeth of the next section are a prolongation of an equal number of the teeth of the preceding; and so on for each section. So that to the eye the reckoner presents a series of successively decreasing teeth, and from its stepped appearance it may be termed a "stepped reckoner." The stopping or locking half of the cylinder is also stepped to correspond with the stepped reckoner. On the upper axis is a tube, free to slide longitudinally, and having a key fitting into a groove in the axis. The tube carries at its outer end a pinion of 10 teeth gearing with the stepped reckoner, and at its other end a star wheel of 10 rays fitting the stepped stop. A fork projecting below the number slide, fits into a groove round the tube, so that the motion of the number slide is communicated to the tube, whose pinion is thus placed in position to gear with that section of the reckoner, the teeth of which correspond in number with the figure in front of the curved rule. The pinion and star wheel are at such a distance apart, that the latter is always upon the section of the stepped stop, corresponding to the section of the reckoner, with which the former is placed to gear.

On the lower axis, and nearer to the centre of the machine, is a piece movable longitudinally, but carried round with the axis by a pin fitting into a hole at the end of the stepped stop. It is composed of the "secondary carrying tooth," and its corresponding stop, there being an incline on the inner edge of the latter, the use of which will be presently explained. Just above this movable piece, there are, *fixed* on the upper axis, a second pinion of 10 teeth and a star wheel. The pinion is so set, that when the piece below it is close up to the stepped stop, the secondary carrying tooth passes it by; but when the piece is moved inwards, this carrying tooth gears with the pinion and when revolving, moves it one tooth forward. As soon as this has taken place, the incline comes in contact with a pin in the frame of the machine, which pushes the piece into its former position.

Under the discs on the circle, the before-mentioned upper axis carries two reversed bevil wheels of 10 teeth each, on a tube free to move longitudinally, but carried round by a key fitting into a groove on the axis. These wheels are moved longitudinally by the

regulator, as may be seen by taking off the circle. Between them (and in gear with one or other of them, according to the position of the regulator) is a similar bevil wheel on the spindle of the corresponding number disc, and above the wheel is the "primary carrying tooth." As the pinions and the bevil wheels have each 10 teeth, and the number disc has 10 figures, every tooth when the pinions are moved counts one, either forward or backward on the disc. When the figure in the aperture over the disc passes from 9 to 0 in addition, or from 0 to 9 in subtraction, the primary carrying tooth passes the wedge-shaped end of the upper arm of the carrying lever, which it pushes back. This carrying lever moves on a perpendicular axis. Its lower arm clutches a pin in the shaft of a fork under and parallel with the lower axis beneath the next higher number slide. This fork fits into a groove round the movable piece of the secondary carrying tooth, which it shoots inwards into position for adding or carrying 1 as above described.

Each lower axis is timed to operate on the pinions above it, at least one tooth later than its neighbour to the right, to allow time for the latter to shoot the carrying tooth. This is not the case, however, with the axis under the lowest Number Slide but one, and the Index Slides B and C, which are all timed to act simultaneously with the lowest Number Slide.

It will be seen that each revolution of the motive-handle and consequently of the reckoners, causes the latter to move the pinions above them as many teeth as there are on the sections of the reckoners over which the pinions are respectively set by the number slides. This motion of the pinions is communicated to the number discs, and therefore adds or subtracts accordingly.

Thomas de Colmar's straight machine is very similar in mechanism and is a little cheaper than the circular. I have tried both and personally prefer the straight machine; my reason is mainly because it is lighter and more portable, the straight arithmometer is contained in a box $33 \times 7 \times 3{\cdot}5$ inches, whereas Edmonson's circular is very much larger and heavier.

Either of these machines will add, subtract, multiply, divide and extract the Square Root.

As a sample of the speed of operation, it may be stated that the following multiple is worked in less than half a minute: $93{,}857{,}926 \times 987{,}416{,}381{,}792 = 92{,}676{,}853{,}693{,}421{,}283{,}392$.

It multiplies and adds, or multiplies and subtracts, in one operation, which takes no more time than multiplying alone.

It will multiply 12 figures by 12 figures (giving a product of 24 figures); or, with a multiplicand of 8 figures it will work a multiplier of any number of figures, however great. It will divide a dividend of any number of figures by a divisor of 8 figures, and will carry a quotient to any number of places of decimals.

The method of working either machine is learnt in a very short time, and will be found invaluable to those who desire to get out

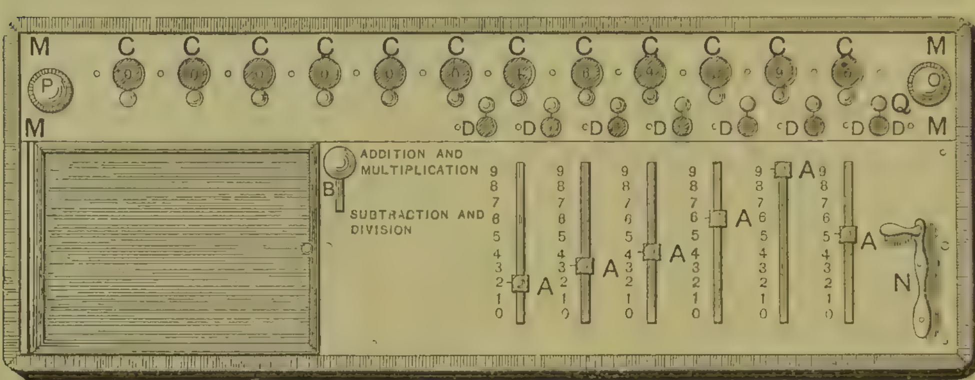

FIG. 4.—THE STRAIGHT ARITHMOMETER.

A, Small brass studs gliding in slits. B, Button by means of which the machine is adjusted for subtraction (or division) and multiplication (or addition). C, Holes at the bottom of which are seen the results of the operations. D, Holes in which are seen figures indicating the multiplier and the quotient. M,M,M,M is a movable plate. N, The handle which is to work the machine. O, Right button, by means of which all the figures in D. D. can be adjusted to zero. P, Left button, by means of which all the figures C, C, C, can be placed at zero.

elaborate life tables, or other tabular matter involving the close application of the mind for many hours to figures.

In the *Journal* of the Institute of Actuaries will be found papers by General Hannyngton (vol. xvi.), and by Mr. Peter Gray, giving directions in considerable detail for performing the most elaborate calculations in the formation of life contingency tables by aid of the Arithmometer; to these papers the reader is referred for farther information.

[1] Messrs. Stanley, Great Turnstile, Holborn, are the agents for Edmonson's circular machine, 25*l*. Mr. Redfern is the agent for De Colmar's Arithmometre, price 20*l*.

SECTION II.

AIR, VENTILATION, WARMING.

CHAPTER IV.

AIR.

(24) *General Nature of Air.*

Air collected near the surface of the earth is a mechanical mixture of oxygen and nitrogen, with a constant and a small proportion of carbonic acid, together with variable minute traces of other gases, odours, essences, particles of mineral substances, of dead and living organized matter. The air is, owing to the force of gravity, much denser near the earth, and gets attenuated layer by layer as you ascend. A coloured diagrammatic representation of the air envelope to the globe would show accurately the density if the colour was made darkest at the surface and faded gradually into space; it is now believed there is no definite limit to the atmosphere, it simply gets rarer and rarer; if it were possible to make a flight from the earth's surface through the interplanetary space there would be no single point of the passage which could be selected as absolutely destitute of the constituents of the atmosphere.

(25) *Atmospheric Pressure.*

Pressure of the atmosphere varies with locality; there are areas on the globe of almost constant high pressure and of almost constant low pressure. The equatorial tropical regions have a belt of low pressure towards which the trades blow south of the equator, and parallel to it there is a well-defined belt of high pressure of nearly equal breadth throughout; north of the equator there is a belt of high pressure, but it is irregular in form, in its breadth, and in its inclination to the equator. At the south and north

poles there are also areas of low pressure; that at the south pole remains pretty constant throughout the year, that at the north pole is divided into two centres, at each of which there is a diminution of pressure greatly lower than the average north polar depression. It follows then that there are three extensive areas of low pressure, viz., the equatorial belt and the regions of the pole.

The average weight or pressure of the atmosphere in the latitude of London is balanced by a column of mercury 29·905 inches at 0°; this is equal to a pressure of 14·73 lbs. on the square inch. The standard atmosphere to which, in measuring gases or calculations generally, mixtures are reduced is 760 mm. of mercury at 0° (29·922 inches); this is equivalent to 103·3 kilos on a square decimetre.

(26) *The Weight of a Volume of Air.*

The weight of a litre of air, or any other volume, varies according to the value of gravity at the place of observation. At the latitude of Paris the weight of a litre of dry carbon dioxide free air is ·12932 grms.

This is also with but slight difference the weight of a litre of purified dry air in London. The presence of carbon dioxide and moisture in air increases its weight. Supposing the air contain ·0004 per cent. of carbon dioxide, then the weight of 1 litre would be 1·2935 grm. at 0° and 76 mm. pressure; if required to know the weight per cubic foot, it only has to be remembered that 28 litres are equal to 1 cubic foot, therefore the grms. per cubic foot would be 28 times the above or 28 × 1·2935 grms. = 37·218 grms. (or 558·9 grains).

The weight of air in a square mile[1] is no less than 59,133,431,808 lbs., and the carbonic acid which it contains weighs 31,464,899 lbs., which is equal to 8,490,427 lbs. of carbon, or 3,790 tons.

To be able to reduce volumes of air or gas to standard pressure and temperature and to ascertain their weight, is the basis of the principles of ventilation and air movement generally, and therefore should be carefully mastered.

To reduce the volume of air at any temperature, pressure, and

[1] $(5280)^2 \times 144 \times 14{\cdot}73 = 59{,}133{,}431{,}808$, and $59{,}133{,}431{,}808 \times \frac{05321}{100} = 31{,}464{,}899$.

moistness to the standard pressure and temperature we require to apply the laws of Boyle and Charles.

The law of Boyle is :—The volume of a gas is inversely as the pressure per square centimetre, so long as the temperature remains the same, which, translated into simple language, means that if a cubic foot of air is measured at 740 mm. of barometric pressure, to reduce it to the standard pressure it must be multiplied by 740° and divided by 760°.

The law of Charles is that, assuming no variation of pressure, all gases expand $\frac{1}{273}$ of their bulk at 0° for each degree of variation of temperature; in other words, 273 volumes at 0° become 274 at 1°, 275 at 2°, and so on. For example, 1,000 volumes of air at 10° will become at 20° 1035·3; for 273 at 10° becomes 283, and 273 at 20° becomes 293°, hence the volume will increase at the ratio of $\frac{293}{283}$ that is the volume $\frac{293}{283} \times 1000 = 1035{\cdot}3$. The following is then the simple rule for temperature correction of volume. As 273 plus the given temperature is to 273 plus required temperature, so is the given volume to the required volume.

In practice the two calculations are always required simultaneously—that is, correction both for temperature and pressure; for instance, supposing it is required to reduce a volume of air at 761 mm. pressure and 20° temperature to the standard pressure of 760 and temperature 0°, the equations are combined as follows :—

$$\frac{761 \times 273}{760 \times 293} = {\cdot}933$$

To find the weight of moist air $\frac{3p}{8}$ must be subtracted from the height of the barometer before correcting, p being the tension or pressure of aqueous vapour as ascertained from the dew point; thus the litre of air at 0° and 760 mm. pressure (its weight when dry being 1·2935 grms.) would, when moist, weigh 1·2909 grms., or 1 cubic foot = 36·1452 grms. (556·79 grains), because it is now really at a less pressure than 760 mm., for the tension at 0° being 4·6, and $\frac{3}{8}$ of 4·6 is equal to 1·7 mm. of mercury, which must be subtracted from 760, leaving 758·3; then $\frac{758{\cdot}3}{760} \times 12{,}935 = 1{\cdot}2909$ grm. A litre of air with ·0004 per

cent. of carbon dioxide at 15° and 760 mm. pressure will weigh nearly a gramme (·9417), or a cubic foot will weigh 399·4 grains.

(27) *Percentage Composition of the Atmosphere.*

Cavendish, who had not all the refined processes of volumetric analysis at command which we now possess, could find no appreciable difference between the percentage of oxygen in the large number of 500 analyses. He found 100 volumes of purified air to contain 20·833 per cent. of oxygen, the rest nitrogen. The most numerous and accurate volumetric analyses of air which have been made since Cavendish, have been those of Angus Smith, Bunsen, and Regnault. Bunsen found in 15 analyses of air, extreme differences of from 20·970 to 20·840. Regnault found air from different parts of the world to vary from 20·940 to 20·850; country air occasionally attained 21·0 per cent.; the air of Paris also in one instance approached this number nearly, for he records 20·999. Angus Smith found in the most crowded parts of Perth the mean of 22 analyses to give 20·938 per cent. oxygen, while the air of the sea-shore and the heath gave 20·999.

The analysis of the air by the method of Dumas, by which the air is drawn slowly over ignited copper, is, on the whole, capable of greater accuracy than eudiometric methods, and there have been numerous analyses made by this method: the oxygen unites with the copper, forming copper oxide, and the difference in weight between the bright and the oxidized metal gives at once the oxygen, while the nitrogen can be collected in an exhausted flask, and also weighed. In this process the air is carefully dried and freed from carbon dioxide before it enters the tube.

The following are some analyses by weight, but in the second column the weights are translated into volume by dividing by the specific gravity of oxygen (1·10561).

	Oxygen by weight.	Oxygen by volume.	Nitrogen by weight.[1]	
Paris	23·00	20·80	77.00	Dumas.
Brussels	23·06	20·85	76·94	Stas.
Geneva	22·98	20·78	77·02	Marignac.

[1] The percentage volume of nitrogen from this table can be found by subtracting the percentage volume of oxygen from 100, or by dividing the weight percentages of nitrogen by its specific gravity ·97135.

	Oxygen by weight.	Oxygen by volume.	Nitrogen by weight.	
Berne	22·95	20·76	77·05	Brunner.
Faulhorn	22·97	20·78	77·03	Dumas.
Gröningen	22·99	20·79	77·01	Verver.
Copenhagen	23·01	20·81	76·89	Lewy.
North Sea	22·60	20·44	77·40	,,
,,	23·12	20·91	76·88	,,
Elsinore	23·04	20·84	76·96	,,
Guadeloupe	22·68	20·51	77·32	,,
,,	23·14	20·93	76·86	,,

From all of which it appears that the two chief gases, oxygen and nitrogen, vary in percentage within small limits from local and seasonal conditions; the extremes in percentage volume of oxygen being from 20·5 to 21·0.[1]

The gases are not in chemical combination, but simply mixed together—this is proved by three facts. (1) The relative amounts of the gases cannot be expressed by any chemical formula, for the proportions are neither those of their combining weights, nor of any simple multiple of those weights. When the proper proportions of the two gases are mixed together to form artificial air, there is no manifestation either of heat, electricity, or change of volume; which are the usual signs of chemical combination. (2) Air is slightly soluble in water, but the oxygen of the air being more soluble than nitrogen, the air expelled from water by boiling is oxygenized and contains nearly 35 per cent. of oxygen; this could not take place if oxygen formed a compound with nitrogen, water in that case would dissolve the same proportions of the two gases which exist in the air, and the gas collected from water by boiling after the carbon dioxide was absorbed, would have the same composition as the atmosphere. (3) The refraction of the air is precisely the mean of the refraction of oxygen and nitrogen; if air was a compound gas, the refraction would either be less or greater than the mean refraction of its constituents.

Carbon Dioxide (CO_2), known more commonly under the name of carbonic acid gas, is constantly to be found in all air, and must be considered as a natural constituent. The chief sources of atmospheric carbonic acid are—

1. Subterranean sources and from the soil. Poggendorf has calculated that the amount from subterranean sources is ten times

[1] That is, in the open air;—the percentage of oxygen found in mines by Angus Smith occasionally reached very low figures, such, for example, as 18·6 per cent.

greater than all the other sources put together, and that if no causes of diminution existed, the amount of carbon dioxide would be doubled in about 380 years. This carbon dioxide is in part produced by slow processes of combustion continuously going on in the more superficial parts of the earth's crust, and in part from the diffusion of pent-up gas in natural reservoirs, large and small, produced in past ages.

2. The respiration of man and animals.

3. Processes of combustion.

4. Fermentation.

5. The burning of limestone, by which carbonate of lime is heated to redness. Under these conditions it parts with its carbonic acid and becomes caustic lime.

6. The escape of carbonic acid from natural waters in which it is held in solution.

Carbon dioxide is a colourless invisible gas; it is more than half as heavy again as air; 1 litre at 0° and 760 mm. pressure weighs 1·977414 grm. (or 100 cubic inches at 60° F. and 30 inches bar. weighs 47·303 grains); its specific gravity compared with air is 1·5203. On account of its density it can be poured from one vessel to another like water, and hence is liable to collect at the bottom of deep wells, of vats, or similar places. It does not support combustion, extinguishing flame immediately; a candle goes out when the oxygen sinks to 18·5 per cent. and the carbon dioxide rises to 2·5 per cent, but this quantity will not be immediately fatal, for most persons can breathe air containing 5 per cent. for a short period; anything over 5 per cent. causes insensibility in a longer or shorter time varying with different people; undiluted carbon dioxide is irrespirable, causing spasm of the glottis.

Carbon dioxide is quickly absorbed by solutions of caustic alkalies such as soda or potash, or the caustic alkaline earths such as lime or baryta; it is soluble in water, 100 volumes at 0° dissolving as much as 180 volumes of the gas; by increasing the pressure, water may be made to take up proportionately larger quantities; when the pressure is reduced the gas escapes, as witnessed every day in the effervescence of aerated waters, champagne, and similar liquids. Water charged with carbonic acid freely dissolves carbonates of lime and magnesia.

The amount of carbon dioxide varies somewhat according to

locality and season. Risler (*Compt. Rend.* xciv., 1390–1391) has made monthly estimations for a year of the carbon dioxide of the air at Nyon, Switzerland, situate 420 metres above sea level. His minimum number is ·25, his maximum is ·35 per 1,000 volumes of air; the mean of all the estimations being ·30 per 1,000. The mean of numerous analyses by Saussure for the air of Geneva and Chambeisoy works out ·45 per 1,000. London street air, Angus Smith found to average ·36 per 1,000; Manchester, ·40. In inhabited rooms, ill-ventilated stables, and near middens and other sources of carbonic acid much higher numbers are obtained. The carbonic acid derived from respiration has naturally a relation to the other excretory products of respiration in air, and as it can be very easily estimated its amount is a convenient measure of respiratory impurity: this will, however, be discussed farther on.

(28) *The Fixation of Carbon by Plants.—Maintenance of the Composition of the Atmosphere.*

It might be supposed that the atmospheric oxygen would continuously decrease and the carbon dioxide increase, but observation, so far, shows that the atmosphere preserves its composition, although in remote periods geologists believe it to have been of an entirely different composition. The great compensating agency at work keeping down the liability of carbon dioxide to increase is the action of the green chlorophyll of plants on carbon dioxide. This green chlorophyll, under the influence of sunlight, has the extraordinary power of splitting the gas up into its two constituents—*carbon* which it retains, and *oxygen* which it exhales. This fact was first pointed out by Priestly and Ingenhause; it is extraordinary, because carbon dioxide has hitherto only been decomposed in the laboratory by the action of the most powerful agents, such as potassium brought to a high temperature or metals raised to an intense heat or the electric spark; yet every little green cell in sunlight quietly fixes carbon and sets free oxygen; hence there is a continual circle, oxygen being changed into carbon dioxide, carbon dioxide falling again to pieces, the carbon going to build up manifold plant structures, the oxygen to again be changed into carbon dioxide. There is, however, a permanent loss of oxygen ever going on in the oxidation of inorganic matter; such, for example, as the conversion of the protoxides of iron into the

peroxides, and it is not easy to see how in this last case the oxygen can be returned under the ordinary processes of nature. It can, however, be shown that the reservoir of oxygen is so large that this diminution, even continuing for long periods of time, will not affect appreciably the percentage of oxygen. Professor Thorpe gives a very clear illustration of this. "If," says he, "we suppose the atmosphere to be put in a balloon, and suspended from the end of a balance, it would require 581,000 cubes of copper each having a side of 1 kilometre in length, to restore equilibrium."

If we also assume that each individual consumes 1 kilo of oxygen per diem, and that the population of the earth is 1,000,000,000, and further, that the oxygen consumed in the respiration of other animals, and in the oxidation of organic matter amounts to four times that required by man, and also that the oxygen disengaged by plants compensates only for the causes of diminution of oxygen not specified, then even in this exaggerated case, the amount of oxygen abstracted from the air in a century would only amount to fifteen or sixteen of the copper cubes; or, in other words, the abstraction in a century would be only $\frac{1}{8000}$th of the total quantity of oxygen contained in the air —an amount inappreciable by the most exact eudiometric methods known to us.

(29) *Other Gases more or less constantly present in Air.*

Ozone is an allotropic form of oxygen, its chemical formula being denoted by O_3, which signifies that the molecule contains three atoms, whereas ordinary oxygen, O_2, contains but two. 22·4 litres at standard temperature and pressure weigh 48 grammes; it is $1\frac{1}{2}$ times the density of oxygen. Ozone is readily changed into ordinary oxygen by heating it to 300°. It has been liquefied by cold and pressure and is then seen to be a blue liquid. Its oxidizing power is very great. It rapidly corrodes caoutchouc, bleaches vegetable colours, and oxidizes metals. It has such an irritating effect on the mucous membranes of the eyes and nose, that it has even been credited as the general cause of catarrh. It may be produced in considerable quantities by the silent electrical discharge acting on oxygen. Its occurrence in the atmosphere is referred to electrical agency. From the experiments of Houzeau, country air contains one volume in 700,000. In the air over

marshes, in the air of crowded dwelling rooms, and in the air generally of cities it is absent.

The most usual test of its presence is filter paper which has been steeped in a solution of potassic iodide and starch; moistened paper of this kind becomes blue in the presence of ozone, because ozone decomposes potassic iodide and sets free iodine; unfortunately the test is not conclusive because other oxidizing agencies have the same property.

Acids.—Nitric acid in very small quantities exists in most air. Sulphurous acid is ever present in the air of towns. A town atmosphere is, from the continuous combustion of coal containing sulphur compounds, sufficiently acid to turn in a few hours moistened blue litmus paper red.

A. Ladureau (*Ann. Chim. Phys.* 5, xxix., 427–432) examined the air of Lille for sulphurous acid gas: he found on an average a cubic metre to contain 1·8 c.c.; on calm days this was found to increase to 2 c.c., on stormy days it decreased to 1·4 c.c.

Ammonia.—Traces of ammonia are always present even in the purest air. Mr. Horace T. Brown found a million parts of country air, when the samples were collected two metres from the ground, to contain from 5·102 to 6·085 parts of ammonium carbonate; the air of a town contained from 4·059 to 8·732 parts of ammonium carbonate. He considers the normal amount to be about 6 parts per 1,000,000. Heavy rain decreases the amount of ammonia, but only for a time.

Sulphuretted Hydrogen or its ammonia compound is constantly in the air of large cities like London, as proved by the tarnishing of silver coinage and ornaments. The amount has not been accurately estimated.

Marsh Gas.—There is always in the air a small quantity of gas which is a compound of carbon, probably marsh gas. A. Muntz and E. Aubin (*Comptes Rendus*, cxix., 871–874) have found the amount of carbon dioxide which may be obtained by passing air, previously filtered from dust and deprived of its carbon dioxide, over red hot copper oxide, to amount to between 3 and 10 volumes per 1,000,000 volumes of air. It may be stated generally that the amount of the carbon gas or vapour is represented by a volume of carbon dioxide equal to the 100th part of the volume of carbon dioxide existing as such in the atmosphere.

(30) *Other Substances floating in Air.—Micro-organisms.*

Common Salt is an invariable constituent of all natural air. It is probably in the minute dust floating in the lower layers of the atmosphere; its presence is proved by a Bunsen flame always giving the line called the sodium line when examined by the spectroscope. All air also contains micro-organisms, the spores of fungi bacteria, micrococci and bacilli. Hesse was one of the first who made quantitative estimations of the micro-organisms in air. A tube was coated on the inside with sterile nutrient gelatine and the air to be examined slowly aspirated through the tube; in this way the air was made to give up its tiny load of germs, for in passing over the moist sticky gelatine, the minute seeds would adhere. On putting on one side the tube, and keeping it at common room temperatures, the little colonies would grow at all the points which had received a seed or germ, and the points would in a few days be visible to the naked eye. They were afterwards examined by the microscope and their general nature determined.

Dennis, Miquel, Carnelly and Haldane, Greenleaf Tucker, and others have all made interesting researches as to the contents of the air of different places in micro-organisms. The chief results are summarized in the table on the following page. In the latest research, that of Greenleaf Tucker,[1] the micro-organisms were filtered through and arrested by a closely-packed layer of sterilized sugar to which afterwards the nutrient liquid was added.

(31) *The General Difference between Town and Country Air.*

The following is a representation of what is constantly found in town and country air, omitting in the enumeration strictly local airs, which may contain any gas almost that is known to science, and also omitting mineral and non-living but organic dust.

Country Air.	Town Air.
Nitrogen	Nitrogen
Oxygen	Oxygen
Aqueous vapour	Aqueous vapour
Carbon dioxide	Carbon dioxide
Ammonia	Ammonia
Nitric acid	Sulphurous acid
Ozone	Nitric acid
Marsh gas	Sulphuretted hydrogen
Common salt	Marsh gas
Micro-organisms	Common salt
	Micro-organisms

[1] See *Public Health,* vol. ii. No. 2. 1890.

Table XII.

Micro-Organisms in Air from Various Sources.

Place.	Season of Year.	Micro-organisms per 10 litres of air. Bacteria.	Moulds.	Total.	Authority.
Sea air (Atlantic Ocean) . . .	—	0	0	0	Dennis
High Mountains	?	...	...	0·01	Miquel
Moorland	August	0	3·5	3·5	Carnelley & Wilson
Country	Ann. Average	...	...	4·6	Miquel
,, ...	Autumn	...	...	6·8	—
,, ...	August	...	...	14	P. Frankland
Dundee, suburbs	Winter	0	1	1	Carnelley & Haldane
,, town, open places, night	,,	1·5	0	1·5	,, ,,
,, town, close places, day	,,	5	·5	5·5	,, ,,
,, town, open places, day	,,	7	5	12	,, ,,
,, town, open places, day	Spring	12·8	0	12·8	Carnelley & Wilson
Norwich, Cathedral Close . .	?	...	...	18	P. Frankland.
Paris, Rue de Rivoli	Ann. Average	...	...	39	Miquel
,, ,, ,, ...	August	...	...	44	—
London, open places	?	...	...	24	P. Frankland
,, roof of ScienceSchools, S. Kensington . . .	Ann. Average	...	...	36	,,
,, ,, ,, .	August	...	...	105	,,
,, St. Paul's Churchyard.	?	...	...	70	,,
Sewers (Paris)	?	...	...	9	Miquel
,, (Bristol)	Summer	...	...	20	Haldane
,, (Westminster & Dundee)	Spring	79	10	89	Carnelley & Haldane
Royal Infirmary, Dundee . .	Winter	42	17	59	,, ,,
Hospital for Consumption, Brompton	?	...	...	72	P. Frankland
Hôpital de la Pitié, Paris . .	Ann. Average	...	...	96	Miquel
Bedrooms at Night— 3 or more roomed houses, Dundee	Winter	85	5	90	Carnelley & Haldane
2 do.	,,	434	26	460	,, ,,
1 do.	,,	585	15	600	,, ,,
Mechanically ventilated schools, Dundee	,,	160	6	166	,, ,,
Naturally ventilated schools, Dundee	,,	1510	10	1520	,, ,,
Jute Mills, Dundee	,,	1140	460	1600	,, ,,
Outside Boston Hospital, U.S.	November	10	7	17	Greenleaf Tucker
,, ,, .	December	14	6	20	,, ,,
,, ,, .	January	13	3	16	,, ,,

CHAPTER V.

THE GENERAL PRINCIPLES OF VENTILATION.

(32) *The Mechanism by which the Air of Rooms is made Impure.* To understand the mechanism of air contamination of dwellings, it is, in the first place, essential to have some knowledge of the laws of gaseous diffusion, and also of the changes which take place in respiration.

Diffusion of Gases.

Carbon dioxide is $1\frac{1}{2}$ times as heavy as air. If a jar of it be placed in a still atmosphere, and the stopper of the jar removed, the gas will remain for a short period in the jar, but ultimately an analysis of the air in the jar and that of the room will be identical. Similarly, hydrogen is very much lighter than air, and a flask of the gas held mouth downwards will for a short period retain the gas, but not for long. It soon diffuses through the atmosphere.

Diffusion obeys a well-ascertained law, which is, that the diffusibility of two gases varies in the inverse ratio of the square roots of their densities. If we wish to know how rapidly a gas will diffuse in air, we only want to know its specific gravity in relation to air. For instance, the specific gravity of hydrogen is ·06926, that of air 1·000; but taking hydrogen as 1, the specific gravity of air = 14·44; that is, air is 14·44 times as heavy as hydrogen, and the ratio of the square roots of their densities is $\sqrt{14\cdot44}$ to 1, or as 3·8 is to 1. If two equal jars, the one containing hydrogen, and the other air, be placed in a room, and the

whole of the hydrogen diffuse in 1 hour, the air of the jar will diffuse in 3·8 hours; so, again, as the inverse square roots of the densities of hydrogen and carbon dioxide are as 3·8 is to ·8, which is nearly in the relation of 1 to 5, it will require 5 times the time for an equal quantity of the heavier gas to diffuse—that is, if it takes 1 hour for a litre of hydrogen to diffuse, it will take 5 hours for a litre of carbon dioxide to diffuse; or, if put into an apparatus called a diffusiometer, for every 3·8 c.c. of hydrogen which diffuses, ·8 c.c. CO_2 will take its place.

This diffusion of gases takes place through porous substances, such as plaster, walls, and very thin animal membranes; but if the porous material has very fine pores, and is of considerable thickness, the rates of diffusion are different, for under such circumstances the pores act as so many capillary tubes, and the law governing the transit of gases through capillary tubes is different to the above.

In the respiration of animals, the air on entering the lungs comes in contact with the capillary blood-vessels of the lungs, the walls of which are very thin, and diffusion takes place. If the blood were simply an ordinary organic liquid, the gases of the air would be absorbed according to their solubility at the particular temperature and atmospheric pressure at the time of inspiration; but the blood has peculiar properties. The venous blood contains in the red corpuscles a substance called hæmoglobin, which forms a well-defined, although loosely bound compound with oxygen. The venous blood, on arriving at the lungs with its myriads of hæmoglobin-containing corpuscles, greedily absorbs oxygen, oxy-hæmoglobin being formed. The blood now becomes bright (arterial) red, and carries the oxygen to all the tissues. The living tissues soon rob the oxyhæmoglobin of its oxygen, reducing it to hæmoglobin. Upon this happening, the blood becomes of a dark (venous) colour, nor does it recover its bright hue until the lungs are again entered. The red corpuscles may be likened to legions of little boats, whose office it is to float with the circulatory tides to the lungs, for the purpose of each taking in a tiny cargo of oxygen. After discharging it, they return for more. While the corpuscles are thus busy in collecting and dispensing oxygen, there is at the same time a transpiration of carbon dioxide, for there is so far a true combustion in the tissues—that is, there is develop-

ment of heat; oxygen unites with carbon, and carbon dioxide is formed. This absorption of oxygen and expiration of carbon dioxide is quite independent of atmospheric pressure. On the other hand, whether less or more nitrogen is absorbed is intimately connected with the height of the barometer. If the barometer sinks, nitrogen escapes from the body until equilibrium is restored; if the barometer rises, then a certain absorption of nitrogen appears to take place.

There is also a considerable expiration of aqueous vapour.

(33) *Composition of Expired Air.*

Expired air then is deficient in oxygen, is rich in carbon dioxide and in moisture. It also contains very often organic volatile bodies, such as ether and gases derived from food or drink consumed, and it is not unfrequently somewhat ammoniacal. A persons' breath smells of ether after taking alcohol, the expired air will blacken silver after eating eggs, and eructations of marsh gas are known to occur in some forms of indigestion. The healthiest person's breath also contains other forms of organic matter, the exact nature of which is obscure.[1] The most recent researches show that the breath is singularly free from micro-organisms, the lungs acting as a very efficient filter.

The content of carbon dioxide in expired air varies according to body weight, to age, and other circumstances, such as activity or rest. It may be taken generally as 5 per cent. of the volume of the expired air in the case of an average-sized man doing ordinary work. Speck, in 41 experiments made on his own breath under different conditions, found a maximum of 5·43 per cent. and a minimum of 3·33 per cent., while the oxygen also varied from 15·01 to 17·21 per cent.

Pettenkofer and Voit made some very elaborate researches on the amount expired of oxygen, moisture, and carbon dioxide, of two healthy persons, during the 24 hours, under very different conditions of food and labour.

[1] R. Wurtz (*Comptes Rend.*, cvi. 213—214) drew the air expired from the lungs through a 1 per cent. solution of oxalic acid. He found ammonia to be the chief product; but besides this, isolated a base the hydrochloride of which had a peculiar odour, and formed crystallizable soluble salts with the chlorides of gold and platinum.

The following are mean numbers of some of Voit and Pettenkofer's researches :—

	Carbon dioxide in the 24 hours.	Water in the 24 hours.	Oxygen consumed in the 24 hours.
	grms.	grms.	grms.
At rest	716	821	761
At work	1187	1777	1072
	Ordinary Diet.		
At rest	928	931	831
At work	806	1151	650
	Diet Rich in Egg Albumen.		
At rest	1020	1168	863
	Nitrogen Free Diet.		
At rest	839	925	808

The facts given with regard to the respiratory contamination of air may be summarized as follows :—

An adult man at rest consumes in 24 hours about 816 grms. of oxygen, part of which is retained in the body; part is expired in the form of CO_2. The oxygen retained amounts to from 120 to 200 grms., or 439 litres. The carbon dioxide will be about 870 grms., or 439 litres. He will also separate nearly a litre of water. At work these quantities will be increased. In ordinary not very laborious occupations, he will consume 861 grms. of oxygen, and will exhale 996 grms. (504 litres) of CO_2 and 1,464 grms. of water.

A man will therefore, under ordinary conditions, in the 24 hours, spoil about 3,000 litres (105·9 cubic feet) of air, and if undergoing any exertion 3,700 litres (130·7 cubic feet) or more. It is not far from the truth, and easy to remember that adults spoil every hour about 5 cubic feet of air (140 litres)—that is, render 5 cubic feet of air absolutely irrespirable.

(34) *The Contamination of Air by Animals.*

It is of practical importance in a public health point of view to also study changes in the air produced by the respiration of cattle, horses, and domestic animals, the more especially because there are many dwellings in which the atmosphere is common to beast and man; for instance, in the case of stablemen with rooms over a stable, in which the separation is merely porous lath and plaster and the floor boarding.

There is one peculiarity with regard to the contamination of

the atmosphere by sheep, pigs, horses, and cattle generally, and that is the large quantity of marsh gas which escapes from the intestine. A certain quantity is occasionally produced in the human body, and also contaminates the air, but it is entirely insignificant to the regular and normal production of the intestinal gases of the herbivora.

Regnault and Reiset have made some excellent determinations of the amount of oxygen consumed, the carbon dioxide and marsh gas exhaled of sheep, pigs, and calves. The following is an abstract of the results of their investigations:—

TABLE XIII.

	Weight of animal in kilos.	Oxygen consumed. grms. per hour.	Oxygen consumed per kilo of body weight.	CO_2 exhaled.	Nitrogen.	Marsh Gas (CH_4) in litres.
Sheep	67·7	33·51	·495	42·63	·246	1·4
Calves	97·3	45·87	·480	54·54	·280	1·3
Pigs	105·6	49·30	·477	60·50	·025	·1

Presuming that the ratios found by experiment for calves hold good for cows and horses, an average-sized cow of 230 kilos weight would consume 110·4 grms. of oxygen per hour, and would exhale 128·8 grms. of CO_2, and 3·07 litres of marsh gas. It would therefore render every hour 371·4 litres (13·2 cubic feet) of air irrespirable. Horses would give similar numbers.

Sheep of average size spoil 112·6 litres (3·97 cubic feet) per hour of air; calves 154·2 litres (5·20 cubic feet); pigs of moderate size 165·8 litres (5·85 cubic feet); rabbits about 10 litres (·37 cubic feet); fowls, 1·0 litre (·037 cubic feet); medium-sized dogs, 23·5 litres (·79 cubic feet); a cat, 10 lbs. in weight, 17·8 litres (·6 cubic feet).

If we could only regard respiratory impurity, it would be correct to say that 10 sheep contaminated the air in about the same degree as 8 men; that calves and pigs were more than equal to a man; that 14 rabbits or 140 fowls were equal to a man; but in practice such animals contaminate the air very much more than the above, for they are ever associated with their own excreta, and their intestinal gases passing into the air are additional impurities.

(35) *Quantity of Air required per Head per Hour.*

Ventilation is the art of supplying without perceptible draught[1] the requisite quantity of pure air.

It has been already stated that every hour an adult man renders absolutely irrespirable 5 cubic feet of air; a man under certain circumstances—such as in an air-tight chamber containing the necessary appliances to remove promptly the carbon dioxide by a continuous spray of strong potash, to absorb the excess of aqueous vapour by means of anhydrous chloride of calcium, and in some way or other to deal with organic matter evolved from the lung—would live for an indefinite time if supplied hourly with about 28 litres or a cubic foot per hour of oxygen, for the nitrogen of the air is used over and over again. In the apparatus invented by Fleuss, this problem is partly accomplished; with the aid of the apparatus, which essentially consists of an ingenious respirator connected with a reservoir of oxygen and a rubber sponge saturated with caustic potash, a man may cut himself off entirely from the external air, and in this way descend into the ocean depths or into mines rendered dangerous from choke-damp. Operating under ordinary conditions, however, there are no means at hand to remove the impurities of the breath, and the only way which is found to answer is by enormous dilution. It is generally recognized that to keep the air in the highest degree of practicable purity, no less than 3,000 cubic feet per hour of air is required; this quantity is 600 times the amount of air spoilt. Multiplying then by 600 the cubic feet of air which the different animals render irrespirable, we get the following theoretical amounts of air which should be supplied per hour to animals:—

	Cubic feet per head per hour.		Cubic feet of space.
Horses	7,920	= under ordinary conditions to	1,584
Cows	7,920	,, ,,	1,584
Pigs	3,510	,, ,,	702
Calves	3,120	,, ,,	604
Dogs	474	,, ,,	95
Cats	360	,, ,,	72
Rabbits	222	,, ,,	44
Fowls	22	,, ,,	4

[1] The feeling of draught is not always produced by an actual current of air; if, for instance, a person should sit by a cold wall, there is a radiation of heat from the person's skin, causing the same sensation and the same effects as if blown upon by a current of cold air.

It has been already stated that carbon dioxide, although in small quantities in itself not injurious, nevertheless has such a close relationship with other impurities—the air pollution rising and sinking with the increase or decrease of the carbon dioxide—that its estimation is utilized as a measure of impurity. The standard Dr. Parkes adopted was ·6 carbonic acid per 1,000 volumes of air. If this number is adopted, then the ventilation, to be successful, must not allow the carbonic acid to exceed this. Experiments were made both by Dr. de Chaumont and the late Dr. Parkes, in which they found the organic impurity of the air was perceptible when the carbon dioxide rose to ·6 per 1,000 volumes (*i.e.* ·0006 in each cubic foot). This standard is a high one, and difficult to attain, but experience has shown the correctness of Dr. Parkes's views, and the standard is now generally accepted.

For the purposes of air supply the weight of a man may be taken as 140 lbs., which is the mean number of lbs., deduced from British statistics by Dr. W. Stephenson, for males of the labouring classes between the ages of 25 and 30; the average weight of the non-labouring classes is rather more, viz. 154 lbs. Using, however, the standard weight of 140 lbs., and taking 3000 cubic feet of air per hour as the proper amount, the quantity of air to be supplied will for other ages be proportional to the weight of the individuals; the average weight of children of 5 years of age is about 40 lbs., 10 years of age 66 lbs., and 15 years of age 105 lbs.; hence we shall not be far wrong if the necessary air supply be stated as follows:—

	Air Supply.
5 years and under	855 cubic feet per hour.
From 5 to 10 years	1,414 ,, ,,
From 10 to 15 years	2,250 ,, ,,
Above 15 years	3,000 ,, ,,

Parkes and De Chaumont have given simple formulæ by which the amount of cubic feet of air to be supplied hourly so as to reduce the CO_2 to any standard can be readily calculated. One of these is as follows:—Let c be the assumed quantity of CO_2 exhaled by an adult male in an hour, viz. ·6 cubic foot, r the ratio per cubic foot of air to which it is desired the CO_2 should be reduced, and R the ratio of CO_2 naturally in the air, viz. ·0004 per cubic foot. Then $\frac{c}{r-R}$ = required delivery of air per hour in

cubic feet. For example, let r be ·0006, then $\frac{\cdot 6}{\cdot 0006 - \cdot 0004} = 3000$. If the standard of purity be taken not as ·0006, but as ·0009, then $\frac{\cdot 6}{\cdot 0009 - \cdot 0004} = 1200$ cubic feet to be supplied per hour.

Or if the carbonic acid (CO_2) in the air be determined by experiment, and the experimental number be substituted for r, the answer will give the amount of air which has entered and been utilized. Thus if in an experiment the CO_2 in the air be ascertained to be 3·5 per 1000 volumes (*i.e.* ·0035 in each cubic foot), then $\frac{\cdot 6}{\cdot 0035 - \cdot 0004} = 1935\cdot 3$ cubic feet of fresh air which have entered the room and been utilized.

The amount of impurity in rooms, as estimated by the organic matter, the carbon dioxide, and the number of micro-organisms, varies inversely as the cubic space, as the following table[1] well shows:—

TABLE XIV.

IMPURITY OF THE AIR OF SLEEPING-ROOMS IN RELATION TO CUBIC SPACE.

Cubic space per Person.		No. of Houses.	Excess Temp.	Carbonic Acid.	Organic Matter.	Total Germs.
100	180 cb. ft.	14	19	11·5	2·7	80
180	260 ,,	18	19	10·7	2·7	49
260	340 ,,	6	19	10·3	2·1	32
340	500 ,,	4	18	9·2	1·5	42
500	1,000 ,,	6	13	8·6	1·0	6
1,000	2,500 ,,	8	13	6·7	0·7	9·1
2,500	4,000 ,,	4	16	7·9	0·9	13·1

Cleanliness tends to air purity; dirtiness of rooms to air contamination, as the table on the following page shows.

(36) *Atmospheric Impurity from Combustion.*

In our climate we pass a large portion of time by the aid of artificial light, and all artificial lights, with the exception of the electric, contaminate the air with carbon dioxide and sometimes other products of combustion; all these products ought to be led

[1] *On the Ventilation of Schools,* by Sir Henry Roscoe. The results of both tables are based apparently on Carnelley and Haldane's researches.

into the outer air by special shafts, in this way assisting instead of rendering ventilation more difficult, but as this cannot always be done it is necessary to consider to what extent the air should be diluted to neutralize the product from gas, candles, petroleum and other sources of illumination.

TABLE XV.

EFFECT OF CLEANLINESS.

		Space per person.	Carbonic Acid.	Organic matter.	Micro-organisms.
One-roomed Houses.	Clean	295	7·99	2·34	18
	Dirty	200	9 87	3·23	41
	Dirtier	221	10·66	2·42	49
	Very dirty	220	11·01	2·69	93
Two-roomed Houses.	Very clean	273	12·20	1·93	10
	Clean	264	9·34	1·37	22
	Dirty	233	9·40	2·03	69
Unventilated Board Schools.	Clean	167	19·68	3·25	91
	Average	166	14·17	2·90	125
	Dirtier	191	22·47	2·73	198
Ventilated Schools.	Very clean	194	12·50	2·26	3
	Clean	155	12·81	1·48	16
	Less clean	152	10·78	1·75	30

The amount of air-dilution to purify sufficiently the atmosphere polluted by gas or lamps need not be so great in relation to the carbon dioxide as in the case of breath impurity; it will be ample dilution if we supply 900 cubic feet of air for every cubic foot of carbon dioxide per hour evolved by the light, and as a cubic foot of coal gas properly burnt evolves about 2 cubic feet of CO_2, for every cubic foot of coal gas allow 1,800 cubic feet of air per hour.

The following table gives the amount per hour of carbon dioxide which it is stated are evolved when a sufficient quantity of each of the illuminants named is burnt to give a light equal to 20 standard candles:—

	Cubic feet of carbon dioxide evolved.	Cubic feet of air required for sufficient ventilation.
Tallow	10·1	9,090
Spermaceti or wax	8·3	7,570
Paraffin wax	6·7	6,063
Coal gas	5·0	4,500
Cannel gas	4·0	3,600
Paraffin oils	3·0	2,700

A common three-light chandelier will burn about 12 feet per hour, and hence requires 21,600 cubic feet of air to properly dilute the combustion products. It must also be remembered, that coal gas always contains some sulphur compounds which are burnt up to sulphuric acid, and that gas fittings are seldom perfect; hence a gas supply is pretty certain to more or less continuously add its quota of impurity even when not burning. The other means by which apartments are made impure are the presence of any kinds of organic decomposable matter, the oxidation of fresh paint, the drying of size on the walls, and dust either produced in the house itself or driven in from outside. In hospitals, infirmaries and wherever there are sick people, the air is liable to be dangerously contaminated with emanations from the discharges from wounds, or expectoration from diseased lungs; in such cases the greater amount of air dilution and the larger in reason the cubic space the better.

(37) *Velocity of Air which can be borne without Discomfort.*

Having fixed the amount of air to be supplied, the next question is the manner in which this is to be effected, and this again depends upon the velocity with which the air can be supplied (if we adopt natural ventilation) through the ventilators. If it were possible to place a person without discomfort in a cube of 100 feet and drive the outside air through this cube at a high velocity, the amount of cubic space per head would not be of such great importance. It has however been shown by Parkes and others that air at a temperature of between 55° to 60° F. can stream through an opening at a rate of 2 miles per hour (3 feet per second) without causing any discomfort, but at a speed greater than this it becomes perceptible, that is, a "draught" is experienced; warm air of 90° may be brought in at a higher speed than cool, but even in this case there are limits. A cubic space of 500 cubic feet with an inlet opening of 12 square inches could be supplied with 3,000 cubic feet of air hourly, but the velocity would be 7 miles an hour or 10 feet per second. This would of course be so uncomfortable in cold weather, that the tenant of such a room would block up the ventilators. A change of four times in the hour is about the limit which in practice can be borne, hence the minimum cubic space should be 750 cubic feet.

(38) *Principles Governing Air Movement.*

Previous to entering on details of the methods by which ventilation can be accomplished, it is necessary to explain fully the principles which govern air movement.

All simple ventilation depends for its motive power on a difference of temperature between two columns of air, the heated air ascends, the cold air descends. Investigating the reason of this more closely, the cause of an air current is, that under the influence of heat, the specific gravity of a body of air is made lighter than that of the air in its immediate neighbourhood, and just as in the case of liquids of two different specific gravities, the heavier forces the lighter upwards. If, for example, there be two columns of air in a U tube each 10 feet high so long as there is no change of temperature or aspirating force the two columns will exactly balance, and no movement will take place, but if the temperature of the one limb is raised say 20°, then the heated air will expand $10 \times 20 \times \cdot 002$ and became 10·4 feet in height and movement must ensue. The velocity of this movement is calculated by Montgolfier's rule which is constructed on the following data. The velocity in feet per second of falling bodies is nearly equal to eight times the square root of the height through which they have fallen, and fluids pass through an orifice in a partition with a velocity equal to that which a body would attain in falling through a height equal to the difference in depth of the fluid on the two sides of the partition. The air pressure at the surface of the earth is ever varying, but it is taken to average 14 lbs. to the square inch, and this is the weight of a column of air of equal density 5 miles in height. Air therefore rushes into a vacuum at the same speed as that which a heavy body would acquire in falling a height of 5 miles, 1,339 feet per second, or if it rush instead of into a vacuum into a room in which the pressure is less than outside, the velocity with which it rushes in is due (if we disregard friction) to the falling of a body through a height which represents the difference of pressure outside and inside. This velocity can in ordinary cases be theoretically obtained by multiplying the height from the aperture at which air enters to that from which it escapes by the difference of temperature between the outside and inside, and multiplying this by the coefficient[1] of

[1] The exact coefficient is .002039°.

the expansion of air for 1° F. ·002 ; thus a column 40 feet high, and a difference of temperature between the external air and the internal of 20° would give 1·6 for $40 \times 20 \times \cdot 002 = 1\cdot 6$, and 1·6 feet is the height in feet which will produce the velocity of the inflowing current. To calculate the velocity from this the square root of 1·6 must be multiplied by 8 which will give the velocity in one second of time, $8 \times \sqrt{1\cdot 6} = 10\cdot 12$ and this again multiplied by 60 gives the velocity per minute. Or if the cubic delivery be required the velocity per second must be multiplied by the area of the opening and this by 60.

In practice a large allowance must be made for friction; in the case of a Tobin's tube, the tube being short and wide, the allowance of one fourth of the velocity to be deducted would be sufficient, but where the length of the tube is great and its diameter small, one half or more of theoretical velocity will have to be deducted. If one fourth be deducted from the above example the velocity per minute is 455 feet; if one half, then the velocity is 304 feet per minute; if the shaft be a chimney having a cross sectional area of 1 foot by 5 feet, then the efflux in cubic feet per minute will be $304 \times \cdot 5 = 172\cdot 0$ cubic feet per minute.

Quite as important as friction in hindering the action of ventilation is the alteration of specific gravity of contaminated air. In most cases of air contamination the specific gravity of the air is increased and therefore more difficult to move, *e.g.*, the specific gravity of air being 1·000, that of carbon dioxide is 1·529, of sulphuretted hydrogen 1·177, and generally the stinking organic vapours are heavier than air and tend on that account, if the air is still, to hang about the localities from which they emanate, or if there are air currents, the stenches are apt to flow down towards the basements of houses from the upper stories; those for instance who have laboratories on top floors know how readily sulphuretted hydrogen seems to flow down the staircase, and the same is true of ether vapour. It is scarcely necessary to say that in such cases calculations based upon the movements of pure air give erroneous results.

(39) *Inlets and Outlets.*

The great variation in temperature in this country renders it difficult to arrange the inlets and outlets so that they will deal with

the proper quantity of air in all seasons, it has therefore been found best in practice to take some definite standard per head. The size usually accepted is 24 square inches for inlet, and the same for outlet; these are safe figures. The outlets should admit of being closed or regulated in size so as to adapt themselves to the contingencies of very cold weather. The student should nevertheless know how to calculate the delivery of air by any opening if the size of the opening, the height of the heated column of air, and the difference of temperature be known. This may be done from the formula already given. For instance, in the above example, a chimney for that particular difference of temperature has passing through it $172 \times 60 = 10{,}320$ cubic feet per hour; it is required to reduce the size so that 3,000 cubic feet only pass up the chimney when there is a temperature difference of 40°. The size of the opening is at present ·5 square feet, or 72 square inches, and it must be reduced in the proportion of 3,000 to 10,320, $\frac{3{,}000 \times 72}{10{,}320} = 20{\cdot}93$, so that the openings would have to be reduced to 20·93 square inches.

De Chaumont has given a generally applicable and useful formula based on Montgolfier's rules, and giving the discharge per hour in square inches. No correction is made for friction, and therefore in the case of long tubes, the sizes must be increased in the proportion of 3 : 4.

Another kind of formula is given by Mr. Morrison in a valuable paper on the ventilation of tunnels (*Proc. of the Institution of Civil Engineers*, 1876), which will be found useful in calculating the pressure necessary to force air through shafts. Mr. Morrison's remarks are worthy of quotation. He says:—

"The friction of air varies as the square of the velocity multiplied by the pressure against the sides of the passage. This pressure being uniform, its total amount depends upon the total surface, that is, the length multiplied by the perimeter of the cross section. The force required to propel air through any passage is therefore equal to the square of the velocity into the total surface multiplied by the coefficient of friction. It is more convenient to state the force in lbs. per square inch or per square foot, or as so many inches of water pressure; the above result should therefore be divided by the area of the cross section.

"The best form of the formula for practical purposes of ventilation seems to be: $H = \frac{K V^2 P L}{A}$, where

H = head of pressure in feet of air of same density as the flowing air.

L = length of the pipe or passage in feet.

P = perimeter of cross section in feet.

A = area of pipe or passage in square feet.

V = velocity in thousands of feet per minute.

K = co-efficient of friction = 0·03.

"This formula is perfectly general, and may be used for any fluid; H will always be the head stated in feet of the flowing fluid.

"The pressure of 1 foot of air, at 60° F. is 0·0765 lb. per square foot. The pressure of 1 inch of water is 5·2 lbs. per square foot. Therefore if it be desired to reduce any result in feet of air to its equivalent in inches of water, the process is simply to divide it by $\frac{0{\cdot}0765}{5{\cdot}2} = 68$; *e.g.* the head required for a current of 10 miles per hour through a tunnel 7 miles long, the perimeter 83 feet is: $H = \frac{K V^2 P L}{A} = \frac{0{\cdot}03 \times 0{\cdot}880^2 \times 83 \times 36960}{473} = 150$ feet of air = $2\frac{1}{4}$ inches of water.

"For circular passages, taking D for the diameter, the formula becomes $H = K V^2 \times \frac{4 L}{D}$.

"These formulæ are only applicable to passages whose diameter is small in proportion to their length. For short passages the length should be increased by about 50 diameters of the passage: thus the formula for circular passages becomes $H = K V^2 \times \frac{4 (L + 50 D)}{D}$ and that for irregular-shaped passages, $H = K V^2 \times \frac{P L + 200 A}{A}$.

"The value 0·03 is reduced from a formula explained by Mr. Hawksley, Past-President, in a discussion on the Ventilation of Coal Mines.[1]

"In a Paper on the Ventilation of Coal Mines, read before the Geological Society of Manchester in 1862, Mr. Atkinson adopts the same formula as the Author, but gives a constant nearly ten

[1] Vide *Minutes of Proceedings Inst. C.E.*, vol. vi., p. 192.

times that of most authorities.[1] Mr. Atkinson gives a table of coefficients depending on the material of which the passage is composed:—

Material.	Observer.	Coefficient.
Burnt earth	Peclét	0·268
Galleries of coal mines	Greenwell	0·254
Sheet iron (clean)	Peclét	0·067 to 0·105
Cast iron (old and tarred)	Giraud	0·048
Gas in pipes	Hawksley	0·030
Water in pipes	Etelwein	0·030
Sheet iron (old and rusty)	Girard	0·027
Tinned iron	D'Aubuisson	0·025

"In a discussion on Fans, Mr. Greenwell stated that the coefficient of friction varied according to the nature of the sides of the passage, as shown by Giraud, D'Aubuisson, &c.[2] To this Mr. Hawksley replied that these discrepancies arose from badly-conducted experiments; he had had good opportunities of making experiments in mines with long uniform airways, as well as in pipes, and there were not in reality any such differences of coefficients. On another occasion[3] Mr. Hawksley said that, when the density of any elastic fluid did not materially vary throughout the length of the pipe, the same rule as for inelastic fluids applied, and that the general formula was $V = 48\sqrt{\frac{h\,d}{l}}$ V being the velocity in feet per second; this formula, reduced to the form adopted by Mr. Morrison, gives a constant of 0·031. From Eytelwein's formula according to Beardmore Mr. Morrison deduces 0·028 as the constant. In a Paper by Mr. Lowe the constant is given as 0·030, and in an old formula, the constant is given as 0·028. From experiments on the pneumatic tube from Euston to Holborn,[4] taking the velocity of the air to be that of the carriage, allowing nothing for the work done in moving the carriage, a maximum value is obtained of 0·036, and making allowance for the weight of the carriage, the results give a probable value for the constant of 0 027. The experiments in Lime Street tunnel Liverpool are not well suited for deducing a constant,[5] the length, 1,200 yards, being hardly as great

[1] Quoted also by C. Cope Pearce in the *Transactions of the South Wales Institute of Mining Engineers*, vol. v. The figures, however, are taken from the original.
[2] Vide *Minutes of Proceedings Inst. C.E.*, vol. xxx., p. 304.
[3] *Ibid.*, vol. xxxiii., p. 53.
[4] *Engineering*, 23rd Aug., 1872.
[5] Vide *Inst. Mech. Eng. Proceedings*, 1871, p. 22 *et seq.*

in proportion to width as is desirable. From the data given, making use of the formula for short passages, the constant comes out 0·049; but the velocity of the air may have been higher than taken: a difference of 20 per cent. would bring the constant to the same figure as the others. From experiments made at Crewe, shortly before the ventilation of this tunnel was carried out, the following formula was deduced:—

Discharge in cubic feet per hour, $1{,}314\sqrt{\frac{d^5 h}{l}}$; d = diameter of pipe in inches, h = head in inches of water, l = length in yards. This gives a constant for the formula adopted by Mr. Morrison, of 0·029, and he believes that the authorities quoted are sufficient to justify 0·03 as the value of the constant K."

METHODS OF VENTILATION.

(40) *Simple Openings.*

In fine summer weather, people open their windows and doors, and ventilation is easy; it only becomes in this climate a matter for skill and study during the cooler months of the year, hence, in speaking of systems of ventilation, it must always be presumed that the house contains warmer air than that which is external; in such a case the air within will be of less specific gravity than the air without, and the latter will tend to press in at any opening.

If, for instance, there is an opening at the bottom of the room, another at the top, in the absence of wind there will be a steady stream of air from below upwards, but if there should be wind, or if the openings for the *admission* of air be blocked or too small in area, the draught may be reverse—such reverse draughts often occur when windows are open at the top, the air streaming in like a douche of cold water. It has often been pointed out that under such circumstances, although large volumes of air seem to be coming in, the effect on the atmosphere of the room is not commensurate with the draught, the reason being that the vitiated air, having its specific gravity increased by its contaminations, and becoming cooled by the rush of cold air, descends with it to be partly breathed over again.

(41) *Accepted Principles to be applied to simple Natural Ventilation.*

There are certain principles with regard to simple ventilation generally accepted; these are as follows:—

(1) In natural ventilation, no opening for the admission of fresh air to be near the ceiling, but preferably a few feet above the floor.

(2) The inlets for fresh air should always direct the current of air upwards.

(3) The openings for the admission of air should in their aggregate area be larger than those for the efflux of air. Flues or shafts for extracting air should all be of the same height, otherwise (however paradoxical it may seem) one either counteracts the other, or renders the effect less considerable.

In certain cases, however, it is necessary to have ample openings on a level with the boards. For instance, in asylums in which there are wards for imbeciles and idiots, the flooring is so often fouled with excreta, that unless such openings exist, through which the air, rendered heavy and moist by offensive organic vapours, can flow, the wards cannot be kept sweet. So again, the very best method of ventilating a water-closet is to have an opening on a level with the floor into the external air, and a flue near the upper part of the closet. These will sometimes act in one way and sometimes in another, but in either case the offensive air is rapidly diluted and swept away.[1]

Methods of ventilation which are not dependent on mechanical aids or on artificially warming the air, may be classified for practical purposes as follows:—Appliances connected with windows; appliances connected with walls or chimneys; appliances connected with doors; special flues or shafts.

(42) *Appliances connected with Windows.*

The simplest plan of all is that suggested by Dr. Hinckes Bird, the original model of which is to be seen in the Parkes Museum. A board of wood is placed under the lower sash of the window so as to completely block it up. The effect of this is that a

[1] The same remarks apply to stables and cowhouses; in such places cold currents near the surface of the floor will not incommode the animals, for their sensitive parts are not the feet but the loins, and in both cases there is constant floor pollution.

rectangular shaft is made between the upper and lower sashes, up which the external air presses, and being directed upwards, curves gently into the room without perceptible draught. The board is sometimes made with a hinge in the middle, for greater convenience in either placing or removing it. Instead of being placed underneath the lower sash, it may be placed in front of it, and then the window may be opened at the bottom for a little distance, but not so far as to be lifted beyond the upper edge of the board. In this way two rectangular ventilating shafts are formed, the one having its sides formed by the board and a portion of the window and window-frame, the other formed by the upper and lower sashes of the window. In each case the current of air is directed upwards. A modification of this system is the use of a short glass blind, adapted to the lower part of the window. It is, on the whole, preferable to the board, because there is then no interception of light.

Perforated Sashes.—Holes are bored in the lower bar of the upper sash; the air enters vertically, but being divided up into small streams, no draught is perceptible. The objection to this is, that the window-frame is considerably weakened.

Currall's Window Ventilator.—An opening is made in the lower sash-bar, and then a metal plate is fixed inside in a direction parallel to the window-frame, so as to direct the current of air upwards. The vertical section of such a system is, therefore, pretty well that of a right angle. It is in principle the same idea as that of Hinckes Bird, the only difference being that Currall's ventilator is permanently fixed.

Louvres.—Any one who has a Venetian blind has an appliance that can be utilized very effectually as a louvred opening; for the window can be opened, and the sashes placed at any angle, so as to allow the air to come in either upwards or horizontally. But the most common form of louvre is constructed by removing a pane and fixing glass louvres in a metal framework. The louvres are connected together by a simple mechanical arrangement, and can be opened or shut at pleasure. Glass is of course not the only material which may be used as louvres, but most decidedly the best, being most easily cleaned, and not intercepting the light. The proper place for these appliances is not the upper part of the highest panes, but the lowest pane of the upper sash.

Swinging Windows.—These are much used in hospitals and board schools. Sometimes the window swings on a centre pivot, and in this way a very large opening is obtained. Sometimes the upper part of the window opens inwards like a valve, and thus directs the current up towards the ceiling.

Double Windows.—These are very useful in cold weather, as the layer of air between the two windows gets to a certain extent warmed. By opening the outer one at the bottom, the inner one at the top, a very efficient air-shaft is formed, as in Hinckes Bird's plan.

Cooper's Ventilator.—Cooper's ventilator consists of a circular disc of glass, perforated with five or more holes, attached by means of a pivot to a pane of glass similarly perforated. On turning the disc, the holes in the pane and disc can be made to correspond, or not, just as required.

(43) *Appliances connected with Walls and Chimneys.*

Perforated Bricks.—Ellison's conical ventilator consists of cone-shaped perforations in bricks. It may be experimentally proved that if the air is blown in from the narrow to the wide end of the cone, the stream of air widens and spreads, so that draught is not easily felt. Such bricks are very useful placed just behind, and concealed by, the skirting-board.

Direct Openings in the Wall.—One of the best known of these is Sherringham's valve, which consists of a metal box fitting in a hole in the wall, with a heavy flap exactly balanced by a weight at the end of a string passing over a pulley. By pulling at the weight the valve can be shut, or by lifting the weight the valve may be opened.

Stevens' Drawer Ventilator is like a drawer, with the end most remote from the handle wanting. The drawer fits into the whole length of the wall. When it is shut there is no current; when pulled open, the air enters freely, and, striking against the front bearing the handle, is given an upward direction.

Jennings' Inlet is an opening in the wall, through which the air is first led into a small chamber, where the dust can deposit. From this "dust trap" it passes through louvres into the room.

There are many other ways which have been proposed, and are

more or less effectual. Pictures, skirting-boards, cornices, mirrors may all be utilised, both to conceal openings in walls and to give the air a proper direction.

Arnott's Valve is a valve which is used as an exit ventilator. It consists of a light metal flap, swinging inside a metal framework in such a way that it only opens towards the chimney flue; back pressure from the flue causes it instantly to shut.

Boyle's Exit Ventilator is on the same principle, but instead of metal there are a number of light talc flaps.

Openings in Doors.—These are not much made use of; but sometimes a panel is made to open, either pivoted or otherwise.

Currall's ventilator for doors is precisely the same as the one for windows just described.

(44) *Special Shafts or Tubes.*

Tobin's Tubes.—One of the best known and most efficient forms of ventilation is by means of what is called a Tobin's tube. It is a right-angled tube, the one limb leading in a horizontal direction into the outer air; the other, vertical, being in the room. The vertical pipe should not much exceed six feet. Some Tobin's tubes are provided with valves, in order to throw them out of use when not required. The air streams in, and is directed up towards the ceiling, and then falls like water from a fountain, in fine streams, becoming partly warmed during the descent. These tubes may be placed in the corners of the room. They are susceptible of ornamentation, and are nearly always efficient. If a tray of water, or a piece of canvas kept constantly moist, be placed in the horizontal limb, and the air deflected upon the wet surface by metal plates, most of the dust and soot, which otherwise in smoky towns effects an entrance, is deposited.

With the exception of Tobin's tubes, most of the shafts or tubes act in extracting and not in delivering air.

MacKinnel's tube does however combine the two systems and acts both as a delivery and an exit tube. It consists of two cylinders, one inside the other, passing from the ceiling into the outer air. The inner tube is longer than the outer one and projects above it outside, while at its lower end it also projects into the room and carries a circular rim, the rim being parallel

with the ceiling. A gas burner may be placed in the inner tube to cause a greater extraction ; the vitiated air passes up the inner tube and escapes, the colder external air flows down through the annular space between the outer and inner tube, but is prevented from spraying like a douche on the heads of the inmates by the circular rim which compels the air to pass downwards in curved streams, this system has answered well in the case of square or round one storied buildings such as stables.

(45) *Cowls and Extraction Shafts Generally.*

A chimney is of course an excellent extraction shaft when a fire is burning; the amount of air which passes up is enormous, and if the mean temperature of the shaft is known can be calculated from the formula given at page 69. The efficacy of cowls has probably been overrated. In the numerous experiments carried out by the cowl committee, consisting of Mr. Rogers Field, Mr. Peggs, and Mr. Eassie, the result was, speaking generally, that the much advertised cowls had little advantage over a simple tube or shaft. The motive power in the absence of wind is the difference of temperature between the external and internal air, but when wind is present the wind passing over the top of a shaft will aspirate the air and cause movement independent of temperature.

Cowls are under certain circumstances advantageous, for instance, the common way of ventilating ships and steamers is by means of a cowl turned towards the wind, the air is in this way forced into the lower and enclosed parts of the vessel, a windsail again acts in the same way and may be considered a canvas cowl. Cowls whether aspirating or the reverse, fixed or revolving, owe any efficacy they possess to wind, and they are of course of no more use than ordinary tubes in foggy still conditions of the atmosphere just when ventilation is most urgently needed.

If more than one extraction tube is applied for the purpose of ventilating a room, the principle already enunciated that the separate shafts must be of equal height should be borne in mind.

CHAPTER VI.

SYSTEMS OF VENTILATION COMBINED WITH WARMING OR DEPENDENT ON MECHANICAL AGENCIES.

(46) *Gas as an Aspirating Agent.*

GAS and lights generally may be made to purify the air of a room, instead of contaminating it, by placing some simple tube arrangement with a trumpet mouth over each light, and leading the tube out into the open air. The aspirating force of gas may be utilized for the purpose of ventilating small spaces placed in difficult positions. For example, a water closet in the centre of a building may be kept fairly sweet by carrying a tube direct from the outer air in a horizontal position to the floor of the closet, and a shaft led vertically upwards to the roof, and placing in the shaft a tiny jet of gas; in this way the direction of the air is controlled, and the shaft at all times will be warmer than the external air. Special lights for rooms, such as the Wenham, have, when properly fitted up, arrangements by which the products of combustion are carried away by a flue, while the gas itself is supplied with the upper layer of air near the ceiling already somewhat impure.

(47) *Pritchett's Miniature Hot Water Apparatus.*

This is a combined system, by means of which a room is at once warmed and ventilated. It consists of a small boiler, which can be heated by a spirit lamp, or placed on a fire. Attached to the boiler are two cylinders, each made double; the water circulates in the double casing of the cylinders, the effect being to make two shafts, one for the admission of air, the other for its extraction. The cylinders are placed vertically, the outer cylinders being the

hottest and used for the extraction of foul air, the inner cylinders are cooler, but are yet sufficiently hot to warm the entering air.

(48) *Ventilation Depending on Water Power.*

There are several systems which owe their efficacy to the mechanical force of water, for instance, the Eolus water spray ventilator consists essentially of a fly-wheel fitted with fans. A jet of water directed against this causes it to revolve. Such a system can of course be made either to propel air in or to extract air from a room. This simple form of mechanical ventilation has much to recommend it. By regulating the water supply the rate at which the fans revolve can be adjusted to a nicety.

(49) *The Ventilation of Underground Passages such as Mines.*

This section of the subject may be illustrated by an abstract of Mr. Morrison's short account of the ventilation of underground passages, such as mines and tunnels by mechanical means.

The Furnace.—The simplest plan is the furnace, which at one time was the only system employed, and it is still used in many collieries. There is a good deal to be said in favour of its simplicity, but it is only in the case of very great depths that this system can compete for economy with mechanical methods, and even then there are various drawbacks. The useful effect rarely exceeds 5 per cent. of the actual energy given out by the coals, and although, at a colliery, this is often, but wrongly, considered a matter of minor importance, in tunnel ventilation it is of the first consequence.

Air Pumps.—One of the first mechanical ventilators was invented by Mr. Struvé, of Swansea.[2] It consists of a piston, somewhat resembling a gasometer, working in a brick chamber, in an annular space filled with water. The air is admitted by, and expelled through, flap-valves. It is well suited for extracting large quantities of air from collieries at pressures of 5 inches or 6 inches of water; but the large amount of clearance renders it unsuitable where the pressure is sufficient to cause a practical difference in the density of the air. The effective duty is stated

[1] Vide *Inst. Mech. Eng. Proceedings*, 1869, p. 133; and *Trans. Inst. of Eng. in Scotland*, vol. xiv. p. 72.

[2] Vide *Minutes of Proceedings Inst. C.E.*, vol. x. p. 38.

to vary from 40 per cent. of the actual power put into the pump to 40 per cent. of the gross boiler power.

There is a pair of ventilators of this description at Cwm Avon,[1] with pistons 18 feet in diameter and of 7 feet stroke, working 8 strokes per minute. This machine exhausts from 40,000 to 56,000 cubic feet per minute, with a water gauge of 3 inches. A slightly smaller ventilator at Risca Colliery[1] exhausts 43,800 cubic feet per minute, with a water gauge of 2·3 inches.

Exhausters on a somewhat similar principle have been erected at the St. Gothard Tunnel works.[2] These are cylinders hung one at each end of a rocking beam, which alternately dip into annular tanks of water. The space to be ventilated is connected with these air-cylinders by pipes with inlet valves, and the tops of the air-cylinders are furnished with outlet valves. Each time the cylinder rises it fills with air from the pit or tunnel, which in falling it expels through the valves on the top. These exhausters are therefore single-action pumps, while Struvé's are double action. They are intended to work with a water gauge of 6 inches, and their general design renders them suitable for much higher water gauges than Struvé's.

Lemielle's Ventilator.—Lemielle's ventilator consists of a vertical drum, with movable leaves or vanes,[3] placed eccentrically in a casing, so that the leaves lie close against the drum on one side of the casing, but expand as they pass the other, and thus sweep out a certain amount of air at each revolution. There is a ventilator of this description at Page Bank Colliery,[4] Durham, 23 feet in diameter and 32 feet high. It usually works up to about 60,000 cubic feet per minute with a 2·6 inch water gauge, and but occasionally to 97,000 cubic feet per minute with a 6·6 inch water gauge. The useful effect is 36 per cent. of the gross boiler power.

The Steam Jet.—In some collieries the steam jet has been tried with success, as at Lower Moor Colliery,[5] Oldham. The

[1] Vide *South Wales Inst. of Engineers*, vols. v. and vi., *passim*. Paper by C. Cope Pearce.

[2] *Engineering*, 7th May, 1875.

[3] Vide *North of England Institute of Mining Eng. Trans.*, vols. xviii. p. 63 *et seq.*, and xix., p. 2. Steavenson on Mechanical Ventilation. *Inst. Mech. Eng. Proceedings*, 1858, p. 63.

[4] Vide *Inst. Mech. Eng. Proceedings*, 1869, p. 147.

[5] *Engineer*, 19th Jan., 1872.

apparatus consists of seventy-two vertical pipes 5 feet long and 7 inches in diameter, fitted to an iron frame on the top of the upcast shaft: into each is inserted a steam pipe having a nozzle $\frac{3}{16}$ inch in diameter, supplied with steam at 38 lbs. pressure. This rough apparatus exhausts 16,000 cubic feet per minute.

In the working of pneumatic tubes, between telegraph offices in London, the steam jet has been tested against a first-rate steam-engine;[1] at 40 lbs. pressure the engine does most work, but at 70 lbs. pressure the steam jet is superior. The nozzle, in this instance, is constructed in the most approved manner, and the vacuum produced is equal to 23 inches of mercury; but Mr. Morrison does not know of any instance where, with a water gauge of a few inches, such good results have been obtained by a steam jet as by other means. The jet is probably ill suited for exhausting large quantities of air at low pressures.

The Fan.—The best means of ventilation for tunnels seems to be the fan. It is used in collieries and mines throughout the world, and is the only machine that has ever been applied to tunnel ventilation.

The fan erected at Lime Street tunnel[2] is 29 feet 4 inches in diameter, 7 feet 6 inches wide, and runs at forty-five revolutions per minute, is by no means of the most approved construction, but the circumstances of the case are peculiar; at times the tunnel ventilates itself through the fan, which is constructed to allow of this, the heat of the boiler-fires assisting the natural ventilation. When the fan is at work the vacuum in the tunnel near the bottom of the shaft is only equal to 0·14 inch of water, but near the fan it is equal to 0·54 inch. When the air leaves the fan the pressure is equivalent to 0·19 inch of water above the atmosphere, this being the pressure required to drive the air through the chimney into the open air. The fan therefore seems to exhaust 431,000 cubic feet per minute, against a pressure of $0{\cdot}54 + 0{\cdot}19 = 0{\cdot}73$ inch of water, which represents 50 HP. The actual indicated HP. of the engine is 134. When running at forty-four revolutions, but doing no work, the indicated HP. expended in the friction of the engine and machinery is 34. The effective duty of the fan is therefore only 37 per cent. of the gross

[1] Vide *Minutes of Proceedings Inst. C.E.*, vol. xxxiii. p. 16.
[2] Vide *Inst. Mech. Eng. Proceedings*, 1871, p. 24.

power, or 50 per cent. of the net power. The effective duty of many other fans is, however, much higher.

The pneumatic tube from Euston to the General Post Office is worked by a fan in Holborn,[1] 3,080 yards from Euston. This fan is 22 feet in diameter, and is driven at the rate of one hundred and sixty revolutions per minute. The tube is tunnel-shaped, 4 feet wide and 4 feet 6 inches high. The usual speed of the carriage is about fifteen miles an hour. As the tube has an area of 16·3 square feet, the discharge is 20,000 cubic feet of air per minute. The fan is arranged to work either for exhausting the air or for compressing it. At the speed mentioned the water gauge is about 10 inches,[2] and this shows a useful power of thirty-two horses.

The Metropolitan Railway Company once made use of this tube for the purpose of ventilating their tunnel.[3] The tube crosses the tunnel between Gower Street and Portland Road; and valves were arranged so that, on each journey of the carriage from Euston to Holborn, as soon as the carriage passed the Metropolitan tunnel, the valves opened, and the air was drawn from the Metropolitan railway instead of from Euston. But the tube could only be used when the fan was exhausting, and when the carriage was between the Metropolitan railway and Holborn; that is about once an hour for five or six minutes.

Of late years a great many fans have been introduced. One called the Guibal fan seems to give satisfaction.[4] The effective duty of some of them has been stated to be 83 per cent. of the actual power put into the fan shaft;[5] but generally it is not so high. In these fans the casing is concentric with the fan, and quite close to it, with only one opening, the size of which is regulated by a shutter. The chimney is funnel-shaped, to allow the velocity of air to be reduced before entering the atmosphere. The fact that so much of the circumference of the fan is useless for discharge would lead to the supposition that the quantity of air must be less than that discharged from other fans of equal size.[6]

[1] *Engineering*, 23rd Aug., 1872. *Engineer*, 10th Nov., 1865.
[2] Vide *Min. of Proceedings Inst. C.E.*, vol. xxxiii. p. 4.
[3] *Engineer* and *Engineering*, 31st July, 1874.
[4] Vide *Inst. Mech. Eng. Proceedings*, 1869, p. 78. *North of England Institute of Mining Eng., Trans.*, vol. xiv., p. 73. *Engineering*, 9th April, 1875.
[5] Vide *Inst. Mech. Eng. Proceedings*, 1869, p. 152.
[6] Mr. Cowper seems to hold the same opinion. Vide *Minutes of Proceedings Inst. C.E.*, vol. xxx., p. 258.

It seems, however, that the useful effect of these fans is high, and that, for any given discharge and water gauge, the Guibal fan will work with less coal than many others, and with as little as any.

There is a fan of this description working at Thirslington Colliery. It is 36 feet in diameter and 12 feet wide, and at eighty revolutions it will discharge 80,000 cubic feet per minute, under a water gauge of 6·2 inches. A somewhat smaller fan, at Gethin Colliery, discharges 153,600 cubic feet per minute, under a water gauge of 2·6 inches. It is stated by Mr. Wilkinson that he obtained 63,000 cubic feet of air per minute from a Guibal fan, with a similar amount of steam required for 40,000 cubic feet per minute with Struvé's ventilator.

On their first introduction fans were supposed to be applicable only to low water gauges; but it has been found that they will work economically up to high gauges for ventilating purposes. There are some at Grand Busson, near Mons, in Belgium, 30 feet diameter, working at one hundred revolutions per minute with 7 inches water gauge.

To produce a current of air of 10 miles an hour through a tunnel 20 miles long, a water gauge of less than 7 inches is required, or, including an allowance of 1 inch for friction in the air-passages, &c., 8 inches altogether; it is therefore evident that fans are suitable for the pressures required in all practical cases; and as they are better adapted for passing large quantities of air than any other ventilating apparatus, they should be employed in all cases where tunnels are to be ventilated artificially. The best fans appear to utilize more than 70 per cent. of the actual power applied to the fan shaft, or 15 to 20 per cent. less than the indicated power of the engine.

The Blackman Air Propeller.—The Blackman air propeller is a fan. One 4 feet in diameter driven at a speed of 330 revolutions a minute, with an expenditure of one horse power, discharges 15,000 feet per minute.

Engineers have lately preferred to deliver air by pumps rather than by fans, the amount of air being known in this system with certainty. In schools and colleges in Dundee for example ventilating pumps are driven very economically by water motors: the pumps are rectangular wooden boxes, stiffened by iron ribs, and

provided at top and bottom with inlet valves consisting of a number of short waterproof cloth flaps working against a vertical wooden grid. A wooden piston with a vertical travel is held in place and worked by wire ropes above and below, which lead over pulleys to the water motor; the piston is balanced by a counter-weight on the descending branch of the upper rope. A piston 5 feet square, with a stroke of 5 feet, works at 20 strokes per minute and delivers 150,000 feet per hour. These pumps have been designed by Mr. Cunningham, and when a greater volume of air is required he uses revolving pumps of the Roots blower type. These latter pumps are usually driven by a gas engine. The inlets are vertical. The air thus supplied may be warmed before entering the rooms by steam coils.

Cost of Mechanical as compared with Natural Ventilation.—Mechanical ventilation is the only kind of ventilation which can be relied upon for large public buildings such as churches, schools, assembly rooms, theatres, and the like. In the valuable report of Professor Carnelley for the use of the school board of Dundee (1889) he compares the cost and efficacy of the systems of natural and mechanical ventilation, his chief conclusions being as follows:

In schools badly ventilated on the natural system, the micro-organisms increase up to a certain point with increase of wall and floor space, whereas in mechanically ventilated schools where the air is quickly renewed, the micro-organisms decrease with increase of cubic space. This is shown in the following table:—

TABLE XVI.

Cubic Space per Person.	Naturally Ventilated.				Mechanically Ventilated.			
	No. of Cases.	Carbonic Acid.	Organic Matter.	Total Micro-Organisms.	No. of Cases.	Carbonic Acid.	Organic Matter.	Total Micro-Organisms.
Cubic feet—								
50—100	6	21·5	16·2	119	...	...	...	...
100—150	14	15·5	19·6	128	7	14·0	7·8	23
150—200	5	18·9	12·3	150	8	11·4	9·6	14
200—250	9	21·1	16·8	188	5	11·8	12·3	10
250—300	4	17·1	9·5	187	...	...	...	...
300 and upwards.	4	15·1	11·8	12	6	13·0	3·7	2

The cost per head to naturally ventilate a school built to accommodate 1,000 children, as well as to heat, may be put at $2\frac{3}{4}d.$ per head; the mechanical system will cost $7\frac{1}{2}d.$, the difference being thus 19*l.* 15*s.* per annum. The figures refer to Dundee, hence the cost will be greater in towns where coal is dearer, less where coal is cheaper than in Dundee. But in any case 20*l.* or 25*l.* per year per 1,000 children extra should be considered well spent if it conduce to greater purity of air. Carnelley investigated several systems both of heating and ventilating schools, and recommends a fan or fans driven by a gas-engine; also that the fresh air should be blown in not sucked out; that incoming air should be filtered through coarse jute cloth placed diagonally across the large inlet-flue or across the air chamber; that there should be but one main inlet air shaft, freely open at the top, and not fitted with Louvre boards, and lastly that the fresh air inlet shafts in the various rooms ventilated on the mechanical principle should be much wider and shallower than is usually the case, so as to distribute the air in a thin stream.

CHAPTER VII.

WARMING.

(50) *General Principles of Warming Rooms.*

THE nervous system is benumbed by great heat or cold.

Humboldt long ago drew attention to the analogy between the torpor of the larger reptiles during tropical heat and the hybernation of certain animals during winter.

Cold lessens the vitality generally, its stress being most felt by the aged and young; the heat in this country is seldom excessive for a sufficiently long period to cause disturbance to the public health, save indirectly.

The best temperature for intellectual activity is from 62° to 65°, therefore these are the temperatures for living rooms; on the other hand sleeping rooms are best kept much cooler; sleep is generally soundest when the air of the room is a few degrees above freezing point, always provided that the body itself is kept warm by sufficient wraps; it is a great mistake to heat in any way sleeping rooms, that is provided the sleepers are in good health.

The difficulty of maintenance of temperature to any particular degree can hardly be exaggerated. Our houses are as it were little cellular boxes, at the bottom of a vast aerial ocean, which is often more than 20° in excess or below the temperature desired. Nor does it make the practical solution of the problem easier when we have to build the same house for extremes of heat and cold.

(51) *Warming by Open Fireplaces.*

The "pleasant pokeable fire," as an open fire has been called, is peculiarly English; countries like Sweden, Norway, Russia, and

the Northern States, with their extreme winters, have preferred the more economical stoves.

The open fire is of course wasteful: a pound of coal, if all its heat were utilized, would warm a room 20 feet square and 12 feet high 10° above the surrounding air, but quite eight times that quantity has to be used in open grates even of the best construction. On the other hand they have two great merits, they are cheerful and powerful ventilators: most chimneys of ordinary houses extract from 30,000 to 40,000 cubic feet of air hourly.

The best modern grates are of the warm air type, that is cold pure air is conveyed from without by a special flue to the back of the grate, it is then warmed by contact with the heated surfaces and streams into the room.

The following are the principles to be observed in the construction of warm air grates. The bars in front should be as thin as possible, and fitted not horizontally but vertically, the sides of fire-brick, and splayed to an angle of 135°. The back and sides of the grate should be "gilled," the gills projecting into the chamber at the back. The flue leading to the back of the grate must draw its air supply from an unexceptionable source. The warm air must be delivered at the lowest practicable point, the usual place being just below the mantel-board. The grate itself should be raised a few inches above the floor, and if slow combustion is required, the bottom of the grate may be formed of a solid bit of terra-cotta or fire-clay. In places where instead of coal, wood is burnt, the fuel may be on the hearth itself; in that case the air chamber should not alone be at the back of the fire-place, but should communicate also with a space under the hearth; by means of this "hollow hearth," the heat which otherwise would be expended on the stove and ground is in great part conveyed into the room.

(52) *Stoves.*

The old fashioned stove, which may be defined as a sheet-iron box in which the fuel was burnt, and connected with a pipe to lead away the smoke and gases, was an efficient but unhealthy method of heating a room. When in full action a length of the pipe, and no small portion of the stove itself would be heated to redness, the thin iron in that state became of a spongy texture, and carbon monoxide and dioxide freely streamed through, poisoning

the atmosphere. The little floating particles of organic matter in the air would be borne by currents against the red-hot iron and be consumed. The effect of these miniature cremations, small at any given point or moment, was considerable when the process went on for hours and caused the air to feel "burnt and dry," and to have a peculiar smell. The Pensylvanian stove invented by Franklin, was one of the earliest built on correct principles; the modern ones are little more than improvements of this type of stove.

The first principle of a modern stove is that it shall be constructed of materials which will not permit the transmission of gases through the walls; this is attained by the use of fire-clay linings. The stove should be composed of a judicious combination of iron, fire-clay, fire-brick or porcelain. The forms of stoves are so varied that only types of the chief can be described.

Slow-combustion Stoves.—The Meidingen stove is much used in Germany, it is composed of an inner cylinder made up of a series of thick externally fluted rings; the rings are enclosed with a double casing, which casing can be connected with the outer air by means of a pipe. A door fixed in the grate regulates the draught, and when the stove is fully charged the fuel may be made to burn quickly in from three to four hours, or slowly in twenty-four hours, according to necessity.

A slow combustion stove to which was awarded a gold medal at the International Health Exhibition is constructed as follows: The fire-place is lined with fire-clay, there is a door for the reception of the fuel, and there is another door at the lower part of the stove serving the double purpose of admitting air and removing the ashes. The gases of combustion and the smoke, instead of escaping direct into the chimney, are first ignited and then made to pass through two chambers, and they finally escape through the flue; between the divided chamber and the fuel box is another chamber, the office of which is to warm the air supplied to the room. To this chamber a special flue carried underneath the boards conveys the outside atmosphere and it enters the room as warm air. The stove is essentially a slow combustion stove, and is an improvement upon those which are directly supplied with air from outside, for these of course do not ventilate the rooms, because most of them are entirely closed.

Saxon Snell's Thermohydric Grate.—This is more a stove than a grate, combining however the advantages of both. A small boiler is placed behind the grate and communicates with a series of iron pipes alongside of it. These are also filled with water and air is admitted to the room between these hot water pipes. The products of combustion are carried off by a flue, which as may be seen in the St. Marylebone and Notting Hill Infirmary, may be placed underneath the floor, and the grate occupy the centre of the room.

(53) *Systems applicable for Schools and Public Buildings.*

In the warming of schools and public buildings generally a combined system of warm air grates and of hot water or steam pipes is best. The air of school rooms and corridors may be warmed up to 50° by coils or radiators, and wherever more heat is required that additional degree may be obtained by open fireplaces.

Air that has been artificially heated, although heated in such a way that it is not contaminated by the gases of combustion, has nevertheless been changed and deteriorated in quality. Direct observation on the electric state of the air of close ill-ventilated rooms has shown that the electric condition of the air is reversed, and instead of being positive it is that which is called negative or resinous electricity. This change in the electrical state is probably accompanied by other changes such as a diminution of ozone, but direct observations on this point are wanting. The greater the degree the air is heated, the greater the change the air undergoes; hence any form of air heating in which the pipes are brought to a heat beyond boiling water, is to be deprecated.

(54) *The High Pressure System.*

In this system iron pipes of wrought iron are used, they are filled with water; at the highest point, there is a short bit of empty pipe called the "expansion pipe;" there is no boiler, the pipe passing direct through the furnace fire. In this closed system, there is necessarily great pressure, and the temperature and the pressure have a direct relationship. A modern and good improvement consists in the addition of a safety valve. The faults of the system

are the great irregularity in the temperature of different parts of the same coil, and the rapidity with which any slackening of the fire diminishes the heat. The danger from explosion is not great; if a pipe should burst it merely splits and there is a sudden rush of water and steam, but no fragments of metal fly about. Although from the defects mentioned and especially from the liability by the use of high pressure pipes to overheat the air, the writer considers the system objectionable for the purpose of warming houses; on the other hand it is useful for the purpose of heating drying closets and for disinfecting chambers; wherever in short a small space has to be brought to a high temperature.

(55) *Steam Heating.*

This is only suitable for buildings large enough to support the expense of constant and skilled supervision. The advantages of a steam apparatus over a hot water apparatus consist chiefly in the greater ease of application of the heating surfaces, where great inequalities of level occur, especially when the boiler has to be placed above the places to be heated as well as in the smaller heating surface required. The disadvantages are the constant skilled attention already mentioned, the want of permanence of temperature unless supervised with great care; added to this, more fuel is required and the wear and tear is greater than in the case of a hot water apparatus.

(56) *Hot Water Systems.*

The ordinary hot water apparatus consists of a service cistern, a cistern at the highest point—a boiler and pipes extending from the boiler to the highest cistern and from the highest cistern back to the boiler; at any part of the course the pipes can be curled in coils or otherwise arranged to increase the heating surface. The water in the system is continually circulating, the hot water rising from its lower specific gravity in the one pipe and descending when cooled by its higher specific gravity in the other pipe.

The pipes can be usually maintained to 200°, a temperature that does not seem to deteriorate perceptibly the air passing over them.

It may be useful to know how to calculate the length of pipe

required to maintain a room at a temperature of say 50°. If the question is considered apart from the element of time 1 cubic foot of water raised 1° will raise 2,990 cubic feet of air to a like temperature; the element of time can only be determined by experiment. Mr. C. Hood[1] found that an iron pipe 4 inches external diameter, loses ·851 of a degree of heat per minute (*i.e.* 1° in 70 seconds) when the excess of its temperature is 125° above that of the surrounding air.

Therefore 1 foot in length of pipe 4 inches in diameter will heat 222 cubic feet of air, 1° per minute, when the difference of temperature of pipe and temperature of air is 125°. Before this calculation is applied to the practical heating of buildings, many corrections must be made, especially if there is much window surface, for the loss of heat from glass is considerable. Hood found that 1 square foot of glass in still air will cool 1·279 cubic foot of air as many degrees per minute as the internal temperature of the room exceeds the external temperature of the air. Thus if the difference between the internal and external temperature of a room be 30°, then 1·279 cubic foot of air will be cooled 30° by each square foot of glass. Wind of course increases the cooling power very much.

Neglecting losses from doors and crevices, and only considering the windows and the amount of air to be warmed. Hood reckons the quantity of air to be warmed as at least 3·5 to 5 cubic feet for each square foot of air per minute for each person the room contains, and 1·25 cubic foot for each square foot of glass.

The following table saves the necessity of calculation (see Table XVII.)

An example will show how it is used, supposing the temperature in the winter is likely to be 10° outside and the number of feet of pipe is required to be known to supply 40 persons with 12 cubic feet per minute of air at 50°.

[1] Let p be the temperature of the pipe and t the temperature that the room is required to be kept at, then $\frac{125}{p-2} = x$ which will represent the number of feet of pipe that will warm 222 cubic feet of air 1° per minute, when p—2 is different from the proportions given above. If d represent the difference between the internal and external temperatures of the room and c the number of cubic feet of air which are to be warmed per minute, then $x \frac{d.c}{222} = p$, that is, p will be the number of feet of pipe 4 inches in diameter which will warm any quantity of air per minute.

The amount of air required at 50° is therefore 480 cubic feet. Now looking down the first column of the table, find the external temperature, which is 10°, next the temperature 50°, at which the air is required in the horizontal column, the figure under this *i.e.* at the intersection of the two lines is 150, which is the number of feet of pipe of 4 inches diameter, the temperature of the pipe being 200° which will heat 1,000 cubic feet per. minute, and as 480 cubic feet are alone required the simple rule of three calculation $\frac{150 \times 480}{1{,}000} = 72$ gives the length of pipe.

Or instead of so many feet per head, a rule may be drawn from experience that in rooms for every 1,000 cubic feet 12 feet of 4-inch pipe is required to maintain in cold weather the temperature to 50° a room measuring 20 × 40 × 15 requiring 144 feet.

TABLE XVII.

TABLE SHOWING THE QUANTITY OF PIPE, 4-INCH DIAMETER, WHICH WILL HEAT 1,000 CUBIC FEET OF AIR PER MINUTE ANY REQUIRED NUMBER OF DEGREES. TEMPERATURE OF THE PIPE BEING 200° F.

Temperature External Air.	Temperature at which the room is required to be kept.				
°	50°	55°	60°	65°	70°
	Feet.	Feet.	Feet.	Feet.	Feet.
10	150	174	200	229	259
12	142	166	192	220	251
14	135	159	184	212	242
16	127	151	176	204	233
18	120	143	168	195	225
20	112	135	160	187	216
22	105	128	152	179	207
24	97	120	144	170	199
26	90	112	136	162	190
28	82	104	128	154	181
30	75	97	120	145	173
32	67	89	112	137	164
34	60	81	104	129	155
36	52	73	96	120	147
38	45	66	88	112	138
40	37	58	80	104	129
42	30	50	72	95	121
44	22	42	64	87	112
46	15	34	56	79	103
48	7	27	48	70	95
50	—	19	40	62	86

Although as a rule it is much better to trust to radiators and hot water pipes only for corridors and waiting rooms, warming the room itself by open warm air grates, it cannot be denied that a general system which supplies warm air from a distance has certain advantages, the more particularly in those cases where expense is of secondary importance. For instance, in the ventilation of the House of Commons, the foul air is extracted from the ceilings by furnaces connected with powerful upcast shafts; the fresh air is cooled in summer by ice, and is heated in winter by a steam battery; it is brought through a cast iron perforated floor covered with a peculiar open coating of whipcord; this air is partly forced in as required by steam bellows, the air is also washed by passing it through canvas wetted with spray.

The warming and ventilation of a school at Bigelow, U.S., deserves mention, and is thus described by Dr. Hunter.[1] "The ventilation is effected by a plan recently introduced. There is a common central shaft of wood lined with tin carrying the hot air pipes for supplying the rooms. The air enters near the ceiling at a temperature of 100° by an opening 20 × 35 inches, and is exhausted near the floor, passing to the shaft mentioned. The result is good." In this case no motive power is used, the lower cold air falls by its own weight through the lower openings while the warm air streams in through the upper apertures.

In all these general systems of warming, the success greatly depends on a sufficient quantity of warm air being delivered and also on the care taken in keeping all other channels closed save those which are intended to convey the air to the rooms or to extract it; air rushing in by other channels of course deranges the whole system.

[1] *Sixth Annual Report State Board of Health.* Massachusetts.

CHAPTER VIII.

PRACTICAL EXAMINATION OF AIR.

(57) *Examination by the Senses.*

EXAMINATION by the sense of smell, is in a practical point of view of first importance, minute quantities of organic matter, traces of sulphuretted hydrogen, of coal gas, of ether, of carbon bisulphide, of scents of various kinds, empyreumatic matters and many other substances are detected by the sense of smell in such infinitesimal quantity as to rival and in some cases exceed the most delicate chemical and physical methods known to science; on the other hand the senses will not detect considerable quantities of carbon dioxide, carbon oxide, marsh gas, and several other vapours.

The nature of the organic more or less volatile matter which is given off by the skin and breath and makes the air feel so "stuffy" requires farther elucidation and to some extent varies in different individuals. It consists in part of volatile fatty acids and their ethers, and it may be hazarded as a conjecture that the faculty of dogs in scenting out their masters is dependent mainly on the kind and combination of the fatty acid which the particular man evolves in his perspiration.

(58) *Dust—Bacteria.*

In ordinary living rooms the amount of dust will require no estimation, but in the case of factories and work rooms, the amount of dust per cubic foot may be desirable to be estimated. To make some sort of estimation is easy, but to get good accurate results is difficult for the reason that the dust is always imperfectly distributed. The best method is to fix up a large aspirator and pull two or three gallons through a tube at least one

inch in diameter which tube contains for a couple of inches of its length crystals of sugar or sodic sulphate packed sufficiently tight to allow the air to penetrate, the layer farthest from the aspirator being packed loosely and then increasing in density towards the aspirator; at the conclusion of the experiment the soluble filter is removed, dissolved in water, and the solution filtered through a small weighed filter, the filter washed, dried, weighed, and the weight returned as so much per cubic foot; of course the dust collected should also be submitted to microscopical examination.

It is scarcely necessary to say that the crystals must be pure and free from any kind of dirt; to collect the dust in this way is far better than by pulling it through liquids or by the use of small tubes. For quantitative estimations it is essential that there be no draught of any account through the tube, and the only way to avoid this is to use a tube of large diameter and to aspirate slowly.

For the mere qualitative examination of dust, air may be drawn through glycerin or through boiled distilled water. In some researches it will be advisable to surround a tube with ice and salt and draw the air through this tube, thus condensing moisture and any condensable volatile matters.

The bacteriological examination of air is also best performed by drawing the air through closely packed sugar or sodic sulphate or other soluble filter previously sterilized, and then dissolving the filter in water sterilized by boiling and cultivating in the manner detailed at page 160.

(59) *Chemical Method of Estimating Organic Matter in the Air.*

The best chemical method of estimating organic matter in the air is its approximate estimation by means of permanganate of potash.

A known bulk of air is drawn through a little distilled water and the amount of oxygen consumed determined by the Forchammer process.[1]

(60) *Estimation of Carbonic Acid in the Air.*

The simplest process of all, and one which might be used without the smallest knowledge of chemistry, is the phenol-pthalein method.

[1] 10 c.c. of the solution of permanganate [p. 164] and 10 c.c. of sulphuric acid 1 : 3 are added to a known bulk of water, say a litre; the whole is then heated for four hours to 26·6° C. (80° F.). At the end of that time the water is titrated with the hyposulphite solution [p. 165], using KI and starch as an indicator. The value is obtained by running a control with distilled water.

Phenol-phthalein gives to alkaline solutions an intense crimson colour, but it is very sensitive to CO_2 and this property can be taken advantage of to make approximative determinations of carbonic acid in the air. The latest development of the method is that of Lunge and A. Zeckendorf.[1] It requires simply a solution of well ignited sodic carbonate $Na_2\ CO_3$, 53 grms to the litre, coloured crimson by ·02 grm. of phenol-phthalein and a suitable flask and an india-rubber pump delivering about 70 c.c. of air; the india-rubber pump must be provided with valves so as to admit the air in one direction and expel it in another. The pump B is connected with the flask A as in the figure (Fig. 5), so that the air passes through the solution. To make a determination of CO_2 in the air, the pump is worked several times so as to fill the flask with the air to be examined, then 10 c.c. of the sodic carbonate solution are added and the pump slowly worked until the sodic carbonate solution is decolourized and the number of times noted. Very impure air will be decolourized by two complete emptyings of the india-rubber pump (·30 per cent.); for moderately impure air 9–10 (·09–·10 per cent.) volumes will be required. The ordinary air of towns will take twenty-five volumes (·052 per cent.) and the best country air forty volumes (·038 per cent.). G. Lunge and Zeckendorf standardize their apparatus by actual experiment as against the Pettenkofer process and with a pump of 70 c.c. found the following percentages of CO_2 corresponded to the number of fillings of the pump. The air in the flask is not taken into account, for it is a constant quantity. If therefore the operator uses a rubber pump delivering 70 c.c. the table will be sufficiently exact, but with any other size, he must standardize it by actual experiment.

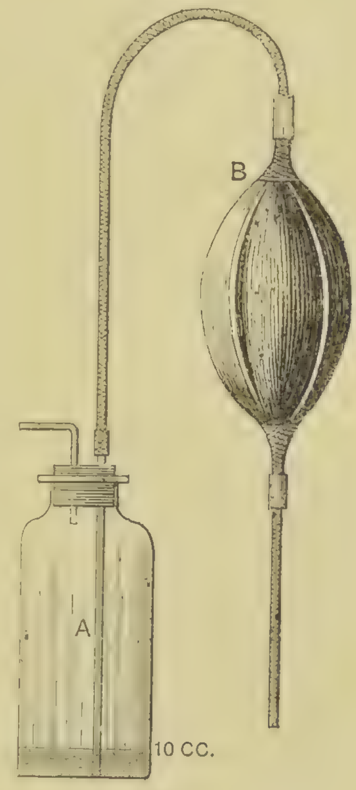

FIG. 5.

[1] *Zeitschr. f. angew Chemie*, No. 14, 1888.

of air. Weight is translated into volume or *vice versâ* by the aid of the following short table :—

Table XIX.

Showing the Relation between Weight and Volume of CO_2 in Milligrammes and Cubic Centimetres.

Milligrammes.	Cubic Centimetres.	Cubic Centimetres.	Milligrammes.
1	·5057	1	1·97
2	1·0114	2	3·94
3	1·5171	3	5·91
4	2·0228	4	7·68
5	2·5285	5	9·85
6	3·0342	6	11·82
7	3·5399	7	13·39
8	4·0456	8	15·76
9	4·5513	9	17·73

It is necessary to observe that a determination is made once for all in the same manner of the amount of CO_2 in the soda solution and the number obtained is a constant correction; an example will make all clear.

20 grms. of the soda solution put into the Schrotter were found after the addition of the acid and boiling up to have lost 12 milligrammes.

20 c.c. of the soda after acting on 2,500 c.c. of air were found to have lost 32 milligrammes, which subtracted from 12 gives 20 milligrammes derived from the air; 20 milligrammes are by the table equal to 10·11 c.c. of carbonic acid, that is 2,500 volumes contain 10·11 of CO_2 or ·4 per cent.

If it is preferred to measure the CO_2 as a gas, this may be done simply by putting a short test-tube charged with more than sufficient acid to neutralize the alkali, in the flask containing the soda; to the flask must be adapted by means of a perforated caoutchouc cork, a piece of glass tubing which in its turn is connected with a piece of rubber tubing some 15 or 16 inches long and has a short angled bit of glass tubing terminating in an almost capillary orifice. All air is to be expelled from the apparatus by boiling the liquid until the steam rushes out with considerable force, the delivery tube is then inserted under mercury in a eudiometer tube also mercury-filled, the value of the divisions of

which are known in c.c. and the acid carefully spilt little by little into the soda by inclining the flask; the gas displaces the mercury in the tube, and the last traces are collected by boiling. The whole is allowed to cool and the gas measured after the usual corrections. In this case also a control experiment must be made on a known bulk of soda solution, and the amount of CO_2 subtracted. This method is not really so accurate as that by weight, as determined in a Schrotter's apparatus, because of the solubility of CO_2 in the water condensed from the steam and floating on the top of the mercury in the eudiometer tube.

(62) *Pettenkofer's Volumetric Method.*

The method which is known as Pettenkofer's consists in ascertaining precisely the alkalinity of clear baryta water then absorbing the carbonic acid by the baryta water, allowing the insoluble carbonate to settle and again taking the alkalinity, which is of course proportionately less.

The best strength for the baryta water is 7 grms. of the crystallized hydrate to the litre; it may be stored in a bottle, stoppered by a doubly perforated cork, the one carrying a short tube loosely filled with pumice-stone moistened with potash; into the other perforation is fitted a long tube bent syphon wise, the one limb of the syphon reaching nearly to the bottom, the longer limb extending outside a few inches below the bottom and being fitted with a short piece of caoutchouc tube and clip, the bottle itself standing on a suitable shelf, and the syphon once filled and kept full the baryta can always be syphoned off clear, and since the air drawn in to replace the liquid drawn out is freed by the potash from CO_2, the alkalinity of the liquid will not alter. The baryta is first standardized by a solution of oxalic acid 2·8736 grms. to the litre (each c.c. = 1 milligramme CO_2), the indicator may be either phenol-phthalein or methyl orange. The solution of oxalic acid is run from a burette into say 25 c.c. of the baryta water coloured by the indicator until by the change of colour it is seen that the exact point of neutralization is reached.

This number is to be taken as the standard, supposing for instance that 25 c.c. of clear baryta water took 30 c.c. of the acid solution and another 25 after acting on a given bulk of air and being

allowed to deposit took 25 c.c. of the acid solution, then a quantity of baryta water equal to 5 c.c. of the standard baryta water has disappeared, it has been converted to an insoluble form. Since the oxalic acid solution is made of such a strength that each c.c. is equal to 1 c.c. of CO_2 it follows that there are 5 c.c. of CO_2 in the air under examination. In this as in the other cases it will be convenient to use for the testing or collecting the air large dry bottles with accurately fitting stoppers. After the air has been pumped in, then 50 c.c. of the clear baryta water are added, the stopper inserted and the liquid well distributed in the bottle, by shaking; after a quarter of an hour or longer the contents are transferred to a stoppered cylinder, allowed to stand excluded from the air until the carbonate is completely settled, and then 25 c.c. of the clear liquid removed by a pipette and the alkalinity determined.

Lime water may be used instead of baryta water; a modification of the method also consists in filtering, with special precautions to prevent the farther absorption of CO_2, the barium carbonate off, converting it into sulphate by adding a sufficient quantity of sulphuric acid, igniting and weighing; one part of barium sulphate is equivalent to ·1891 of CO_2.

(63) *Estimation of Carbon Monoxide, CO.*

It is much to be regretted there is no easy or household test for the presence of this dangerous gas. The best qualitative test is probably that of Vogel: a drop of blood is diluted with water, and the reddish liquid shaken up in a bottle with the air to be examined; the liquid is then examined by the spectroscope, and the position of the bands on the scale noted; a little ammonium sulphide is now added; if carbon monoxide is present, the spectrum will undergo no change. The test is said to detect ·03 per cent.

If a greater quantity of the gas in the air is present than a mere trace, the air, shaken up with a solution of the double chloride of palladium and sodium will produce a black precipitate in the solution, and the quantity present may be approximately estimated by acting on a similar bulk of the solution with air containing known quantities of CO, on similar principles to those detailed at page 98, under the head of "Nephalometric Methods." Before

making the test, sulphuretted hydrogen should be absorbed by passing the air through a solution of lead acetate. Larger quantities of CO are detected and estimated by absorption by cuprous chloride. A solution of cuprous chloride in strong hydrochloric acid absorbs readily CO, forming Berthelot's compound, in which one molecule of CO is united with one molecule of cuprous chloride; on dilution of the cuprous chloride solution, which has absorbed CO with water, and addition of the double salt of palladium and sodium, there is a black precipitate of palladium.

(64) *Sulphuretted Hydrogen.*

Hydric sulphide is detected in very small quantities in air by either exposing strips of paper moistened by lead acetate to the air or by drawing the air through a solution of the same salt. If there is only a dark colour, but no precipitate, the amount may be estimated on colorimetric principles—that is, the colour may be imitated by acting on a similar bulk of lead acetate solution by water containing known quantities of hydric sulphide.

CHAPTER IX.

HOW TO MEASURE CUBIC SPACE AND TO REPORT ON VENTILATION.

(65) *Cubic space allowed by law or by local regulations.*

TABLE XX.

	Cubic Space per head.[1] Cubic feet.	Authority.
Board Schools (minimum allowed, new code)	100	Educational Dept.
General Schoolrooms ,, ,,	130	London School Board.
Graded Schools ,, ,,	117	,, ,, ,,
Dundee Board School, average	152	
Common Lodging House (sleeping rooms) .	300	Local Govt. Board.
Registered Houses let in Tenements—		
(*a*) Rooms used both for sleeping and living	400	Various regulations compiled by Local Govt. Board.
(*b*) Rooms used for sleeping only . . .	300	,, ,,
British Army Barracks minimum	600	Army Regulations.
Prisons, seldom under	750—800	
Non-textile Workrooms	250	Factory Act.
Army Horses (minimum)	1,600	Army Regulations.
,, ,, (in Infirmary)	1,900	,, ,,

(66) *The Cube of Rectangular and Triangular Spaces.*

EVERY sanitary officer should know how to measure cubic space.

(*a*) Cubic space of a square or rectangular room.

This is by far the most common case, the rule being simply to

[1] To obtain roughly the cubic feet per hour it is usual to multiply by five. Thus the Board Schools will give to the scholars only 500 cubic feet per hour, which is an insufficient quantity.

multiply the three dimensions together—that is, height, length, and breadth.

For example: a room 10 feet high, 15 long, and 12 broad, has a cubic space of 1,800 cubic feet, for $10 \times 12 \times 15 = 1{,}800$.

(*b*) Cubic space of a room, the upper part of which has a triangular section.

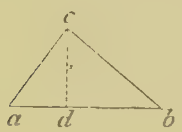

FIG. 7.

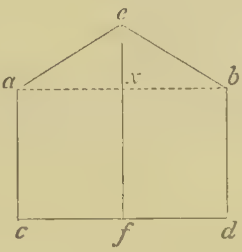

FIG. 8.

This may either be a lean-to roof, such as Fig. 7, or any other kind of roof, such as Fig. 8.

The first process is to obtain the cube of the rectangular space, *abcd*, next the area of the triangular space, *abe*, which, when multiplied by the length, gives the cube of that portion of the room, and the two added together make the total cube.

The area of a triangle, the perpendicular height of which is known (and in rooms the height can always be known), is found by multiplying the base by half the perpendicular height. Thus, in the triangle, *abc*, Fig. 7, the base, *ab*, being 10 feet, and *cd* being 6 feet, the area is 30 feet, for $10 \times 3 = 30$; or, it may be put in another way: multiply base by perpendicular height and divide the product by two.

Applying this principle to the measurement of a room of which Fig. 8 is a section. Supposing the length is 30 feet, the extreme height, *ef*, 15 feet, the breadth, *cd*, 14 feet, and the height of wall, *bd*, 10 feet, required the cubic space.

First cube, *abcd*, $10 \times 30 \times 14 = 4{,}200$; then get area of triangular space, *abe*, which by our rule is half the perpendicular *ex*, that is, 5 or 2·5, and multiply this by the base, 14 feet, and the product by the length, that is, 30 feet—$2{\cdot}5 \times 14 \times 30 = 1{,}050$, which, added to 4,200, = 5,250.

A shorter method of doing this problem is to consider the sectional area, that of a trapezoid, obtain its area, and then multiply by the length.

The rule for obtaining the area of a trapezoid is: multiply the sum of the parallel sides by the perpendicular distance between them, and half the product will be the area. The parallel sides in this instance are *ac*, *ef*; the distance between them is half the breadth, 7 feet; then $10 + 15 \times 7 = 175$, and $175 \times 30 = 5{,}250$, the same as before.

So, again, if a room has either a sectional area, like *abcd*, Fig. 9, in which the side *ab* is parallel to the side *dc*, measure off a perpendicular *de*, add the lengths of *dc* and *ab* together, multiply by the length of the perpendicular *de*, halve the product and multiply by the length of the room or the height, according as the trapezoid figure belongs to a section or a ground plan.

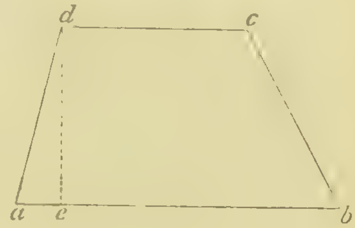

Fig. 9.

Equilateral Triangular Spaces.—It is useful to remember that, although the area of an equilateral triangle can be found by the general rule, in this special case the area can be calculated without measuring off any perpendicular, if one side only is known; the rule being that the area is equal to half the side squared, and multiplied by the square root of three.

Since the square root of three is 1·732, another way of putting it is: halve the side, square it, and multiply it by 1·732. An equilateral triangular space, one side of which was 8 feet, would have an area equal to 27·712 square feet. A cupboard in a room having this area, and 10 feet high, would of course cube out as 277·12 cubic feet.

(67) *Cubic Space of Rooms, the Ground Plan of which is of an irregular Figure.*

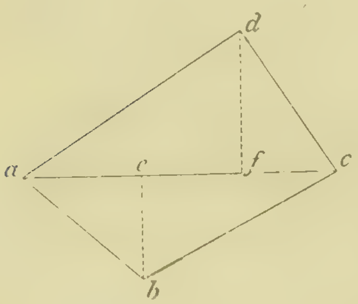

Fig. 10.

In this instance the room may be divided up into triangles, the area of the triangles found and multiplied by the height, or it may be more convenient to consider the area that of a trapezium. The area of a trapezium is found by multiplying the diagonal by the sum of the perpendiculars let fall upon it from the opposite angles, and halving the product. Supposing, for instance, Fig. 10 is the ground plan of a room 12 feet

high. First of all a diagonal is carefully measured along *ac* and found to be 30 feet; perpendiculars are next measured from *c* and *f* to the opposite angles, and these are found to be 5 and 7 feet; required the cubic capacity.

Here the sum of the perpendiculars is $7 + 5 = 12$; the area is $\frac{12 \times 30}{2} = 180$; and the cube is $180 \times 12 = 2{,}160$. Or, by the method of triangles, the base of the triangle *acd* multiplied by the perpendicular *df* gives twice area of triangle *adc*, and the base *ac* of the triangle *abc* multiplied by perpendicular *bc* gives twice triangle area of *abc*, or

$$\begin{array}{r} 30 \times 7 = 210 \\ 30 \times 5 = 150 \\ \hline 2)\ 360 \\ \hline 180 \\ 12 \\ \hline 2160, \end{array}$$

and generally the area of any irregular room may be obtained by dividing it into triangles, and then the cube obtained by multiplying the sum of these areas by the height.

(68) *The Cube of Cylinders, such as pillars.*

It may occasionally happen that in cubing a room the cube of pillars supporting the ceiling will have to be subtracted; the cubic contents, also, of water mains, of wells and cylindrical cisterns are all calculated on the same principles.

To cube cylindrical bodies it is necessary to remember a few elementary properties of a circle, and to know how to get the areas of circles.

The relation of the circumference to the diameter is as 1 is to 3·1416, a number which may be perhaps committed to memory better by making the nonsense word *tofos*—the *t* standing for the three, the *o* for the one, the *f* four, and so on.

It hence follows that the diameter may be known if the circumference is given, and *vice versâ;* for the diameter multiplied by 3·1416 gives the circumference, and the circumference divided by 3·1416 equals the diameter.

To obtain the area of a circle the usual way is to square the diameter, and multiply by ·7854; this number can always be remembered if 3·1416 is remembered, for ·7854 is one-fourth of 3·1416; another method is to divide both circumference and diameter by 2, multiply them together, and the result is the area. The cube of a cylinder is of course the area multiplied by its height.

For instance, take the case of a pillar of two feet diameter and 15 feet high. $d^2 \times {\cdot}7854 \times h =$ cube of pillar, or taking the figures $4 \times {\cdot}7854 \times 15 = 47{\cdot}124$ cubic feet. Supposing the circumference only of the pillar be given and its height, the process is as in the following example. A pillar is 5·2 feet in circumference, and 15 feet high; required its cube:—

$$\frac{5{\cdot}2}{3{\cdot}1416} = \text{diameter that is } 1{\cdot}655$$

$$1{\cdot}655^2 \times {\cdot}7854 \times 15 = 32{\cdot}27, \text{ which is the cubic content in feet.}$$

The area of a sector of a circle is found by getting the area of the whole circle, multiplying it by the number of degrees in the arc, and dividing by 360; this will not often be required, save as a preliminary step to obtain area of segment. On the other hand the areas of segments are frequently found; many bow windows, for instance, are segments of circles, and in order to obtain the cube of the space occupied by a bow window, the ground plan of which is less or greater than a semicircle, the first step is to get the area, and then to multiply by the height.

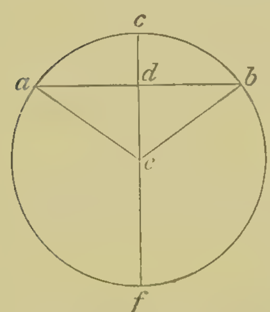

FIG. 11.

The area of the sector *abce* is first obtained, next the area of the triangle *abc*, the two areas are then subtracted one from the other, if the segment is less than a semicircle; or added if greater than a semicircle, this area multiplied by the height gives the cube. Should only the chord (Fig. 11) *ab* and the height or length *cd* be given the diameter and the number of degrees must be calculated out as follows:—

$$\text{Diameter} = \frac{ad^2}{cd} + cd$$

Having got the diameter we know from trigonometry that the sine

$aec = \frac{ad}{ae}$ and from a table of sines the angle *aec*, and therefore *aeb* is obtained from this number, the sum of the two angles equalling the number of degrees in the arc. For instance, given the chord $ab = 8$ and $cd = 2$, ad is $\frac{1}{2}$ of $8 = 4$, and $\frac{4^2}{2} + 2 = 10$, therefore the diameter is 10 and radius *ae* equals 5. The sine of $aec\ \frac{4}{5} = {\cdot}8$, which on reference to a table of sines is equal to 53° 8′, and the whole angle in the sector is therefore twice that or 106° 16′, or the area may be found by the following rule:—to $\frac{2}{3}$ of product of chord and height, add the cube of the height divided by twice the chord $(ab \times gf \times \frac{2}{3}) + \frac{cd^3}{2ab}$. Applying these principles to practice. In the room of which Fig. 12 is a ground plan the length from *a* to *d* is 36 feet, the breadth *de* is 21 feet, the distance from *f* to *g* is 1·4 feet, and the height of the room is 12 feet, required the cubic capacity of the whole. First of all the room is cubed, neglecting the bow $36 \times 21 \times 12 = 9{,}072$, the next step is to obtain the number of degrees in the sector *agb*, to get which we want to know the diameter of the circle of which it is an arc, $\frac{1}{2}$ the chord $ab = 10{\cdot}5$, and therefore $\frac{10{\cdot}5^2}{1{\cdot}4} + 1{\cdot}4 = 80{\cdot}15$. The diameter is then 80·15, and hence the radius is 40·075, the sine $acg = \frac{af}{ac}$ that is $\frac{10{\cdot}5}{40{\cdot}075} = 15°\ 11'$ nearly. The number of degrees in the arc is therefore $2 \times 15°\ 11'$, or 30° 22′. The area of the sector can now be obtained $\frac{80{\cdot}15^2 \times {\cdot}7854 \times 30°\ 22'}{360} = 425{\cdot}6$, from this area subtract the area of the triangle *abc* which is $\frac{1}{2}\ cf \times ab$, or $18 \times 21 = 378$, and $425{\cdot}6 - 378$ gives 47·6 as the area of the sector *agb*, this number multiplied by the height gives the cube $47{\cdot}6 \times 12 = 571{\cdot}2$, and $571{\cdot}2 + 9{,}072$ gives the total cube of the room as 9,643 cubic feet.

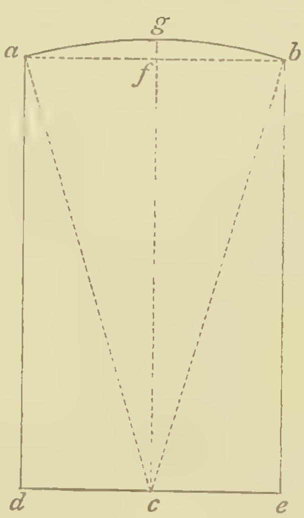

FIG. 12.

(69) *Area of Ellipses.*

The bow windows in some rooms may be in the form of an elliptical curve, and the rule to find the area of an ellipse is, multiply the product of the two diameters by ·7854. If, for instance, in Fig. 12, the bow window is to be considered as half an ellipse, then the major diameter is 21 feet, the minor 1·4 × 2, or 2·8 and 2·8 × 21 = 58·8; 58·8 × ·7854 = 46·18 this must be halved = 23·09, and the cube of the elliptical bow window is 12 × 23·09, or 277·08. The area of hexagons may be obtained by the general rule, multiply the sum of the sides of the polygon by the perpendicular let fall from its centre upon one of the sides and half the product will be the area.

For example, in Fig. 13 let *ab* = 7·3 feet and *op.* = 6·5 feet, the sum of the sides is then 6 × 7·3 = 44·1, and the area equals $\frac{44{\cdot}1 \times 6{\cdot}5}{2} = 143{\cdot}32$. If the cube of a polygonal pillar or other solid be required, it is of course obtained by multiplying the area by the height. Should the side of a polygon and the number of its sides only be given, its area may be obtained by the trigonometrical formula, area $= \frac{n}{4} \times x^2 \times \cot\frac{180°}{n}$

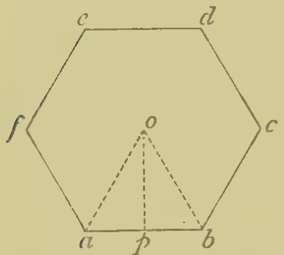

FIG. 13.

when n equals the number of sides, and x = the length of one side. For instance, supposing the area of a regular hexagon be required the side of which is 3. The number of sides is of course 6, therefore $n = 6$

$$\frac{6}{4} \times 3^2 \times \cot\frac{180°}{6} \text{ or } \frac{6}{4} \times 3^2 \times \cot 30° = 23{\cdot}38$$

In this case a still easier way may be adopted, for a hexagon with angles of 30° may be considered as composed of 6 equilateral triangles, the area of one of which may be calculated by the rule already given (page 106), $1{\cdot}5^2 \times \sqrt{3}$, and area of the polygon = 6 × $1{\cdot}5^2 \times \sqrt{3} = 23{\cdot}38$.

The solidity of a cone or pyramid is found as follows:—Mul-

tiply the area of the base by the perpendicular height, and $\frac{1}{3}$ of the product will be the solidity or cubic content. By the aid of this rule the cubic contents of some peculiar shaped roofs may be solved. For instance, let Fig. *abcde* represent a roof, required the cubic content;—ab = 80 feet breadth, ae = 20 feet, dc = 50 feet, and perpendicular height = 10 feet, let *dgs* be a plane section parallel to the end *clp*, then *dpgs* will be a prism, *asdg* will be a pyramid. Cube of prism $\frac{1}{2} \times 50 \times 20 \times 10 = 5{,}000$, cube of pyramid $\frac{1}{3} \times 30 \times 20 \times 10 = 2{,}000$, total 7,000 cubic feet.

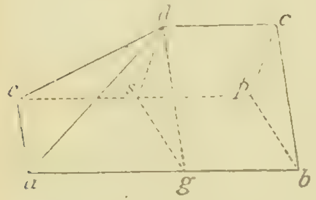

FIG. 14.

(70) *The Cube of Rectangular Prismoids and Frustums of Cones or Pyramids.*

A frustum is a cone or pyramid with its top cut off. In modern built houses there are not infrequently rooms in ornamental towers, which may be treated as frustums. The rule is to the sum of the areas of the two ends, add four times the area of the middle or mean section parallel to the ends, multiply this sum by the height, and one-sixth will be the solidity. For example, let the figure *abche* represent a small room the length of the floor along *ab* is 12 feet, the breadth *ae* or *bp* is 7, and the height is 7 feet, the length of the ceiling is *dc* or *fh* is 8, and the breadth is 4. Here the area of the floor is $7 \times 12 = 84$, the area of the ceiling is $8 \times 4 = 32$, the mean section is the half of the two extreme lengths added together $\frac{1}{2}(12+8) = 10$, multiplied by the half of the top and bottom breadths $\frac{1}{2}(7+4) = 5{\cdot}5$, then by the rule the cube is

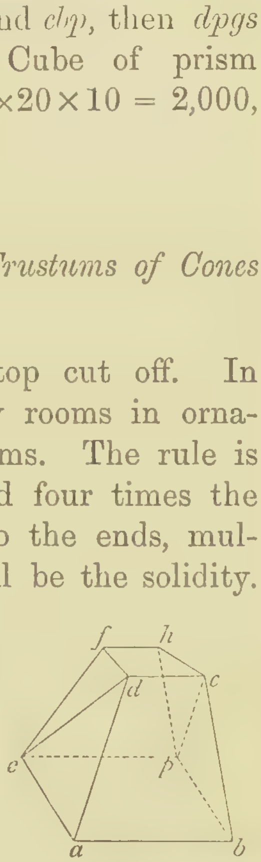

FIG. 15.

$$(84 + 32 + 4 \times 10 \times 5{\cdot}5) \times 7 \times \frac{1}{6} = 392.$$

Cubic Capacity of a Dome.—This may be found by multiplying two-thirds of the product of the area of the base by the height (area of base $\times\, h \times \frac{2}{3}$).

(71) *To Find the Cubic Content of Irregular Spaces.*

The cubic content of irregular solids is most conveniently obtained by applying Thomas Simpson's formula for finding the area of an irregular curvilinear space. To the sum of the extreme sections add four times the sum of the middle or mean sections, and twice the sum of the given intermediate sections: this sum multiplied by one-third the common distance between any section and the next middle section equals the cubic content. This will be found a useful rule for finding the capacity of old-fashioned drains and similar channels. Thus to borrow an example from Tate's geometry. Required the content of a drain, see Fig. 16, whose cross sections taken at 30 feet apart are as follows: the top breadths *ab* are 4, 3, and 5 feet, the corresponding depths are 3, 2, and 4 feet, and the breadth *dc* at the bottom 2 feet, being the same for every section of the drain. Here the sections are all trapezoids; hence we have area of 1st section $\frac{1}{2}(4+2)\times 3 = 9$; area of 2nd section, $\frac{1}{2}(3+2)\times 2 = 5$; area of 3rd section, $\frac{1}{2}(5+2)\times 4 = 14$; area 1st middle section $= \frac{1}{2}\left(\frac{4+3}{2}+2\right)\times\frac{3+2}{2} = 6\frac{7}{8}$; area 2nd middle section $= \frac{1}{2}\left(\frac{3+5}{2}+2\right)\times\frac{2+4}{2} = 9$, hence, by the general formula, observing $2d = 30 \therefore d = 15$.

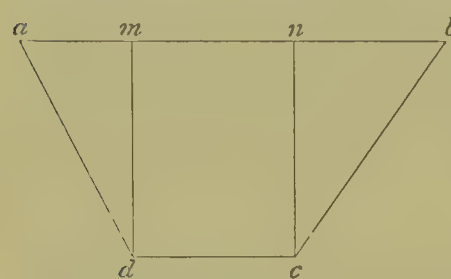

FIG. 16.

$$\text{Content} = \frac{15}{3}\left\{9 + 14 + 4\left(6\tfrac{7}{8}+9\right) + 2\times 5\right\} = 482{\cdot}5 \text{ cubic feet.}$$

(72) *Example of Reports on Ventilation.*

A report[1] by the late Professor de Chaumont on the ventilation of a barrack room, will serve as an example of the kind of report which should be made by a sanitary officer if in any case he should be called upon to make a detailed and scientific examination of ventilation.

[1] *Army Medical Department Statistical and Sanitary Report*, vol. vi., 1864.

Nov. 15th, 1865, 1 a.m., Room 2, G battery, over the stable, intended for 25 men, 21 men actually occupying it. Length, 40 feet; breadth, 28 feet; height, 10·5 feet.

	Cubic Feet.
Gross cubic space	11,760
Deductions	417
	11,343

which gives for 25 men (11,327 cubic feet), per man, 453 cubic feet; for 21 men (actual number) 540 cubic feet.

Ventilation—Inlet Acting.

One stove louvre, 130 square inches; 1′·25 × 2′·16 (⅓ taken). Rate of movement not measurable; no fire.

Outlets.

Two shafts (10″ × 10″), opening obstructed by a board, ½ only taken in consequence, rate not measurable	50	square	inches.
One chimney	60	,,	,,
Total outlet	110	,,	,,
Inlet	130	,,	,,
Total inlet and outlet	240	,,	,,

This gives for 25 men 9·6 sq. inches per man; for 21 men 11·4 sq. inches; actual discharge by chimney, 10,433 cubic feet per hour. Very strong smell of stables.

Results.

Area (room space) per man (25 men)	45	square	feet.
,, ,, (21 men)	53	,,	,,
Total inlet and outlet per man (25 men)	9·6	,,	inches.
,, ,, (21 men)	11·4	,,	,,

Delivery not Measurable.

Discharge for 25 men, per man, per hour	417	cubic	feet.
For 21 men, per man, per hour	500	,,	,,
Discharge for 25 men, per man, per hour	417	,,	,,
For 21 men, per man, per hour	500	,,	,,

Carbonic Acid.

First determination	1·028	in 1,000 volumes.
Second ,,	1·127	
2)	2·155	
Mean	1·077	

Dry bulb, 60°·5; wet bulb, 59°·5; Dew point, 58°·15. Elastic force of vapour, ·493. Weight of vapour in a cubic foot of air, 5·5 grains. Additional weight of vapour required to saturate the air, ·4 grain. Humidity (saturation 100) 94.

At 3·50 a.m.; Dry bulb, 58°; wet bulb, 56°. Dew point, 54°·2; Elastic force of vapour, ·421; Weight of vapour in a cubic foot of air, 4·7 grains; Additional quantity required to saturate the air ·7 grain; Humidity, 87.

Carbonic Acid.

First determination	1·227	in 1,000 volumes.
Second ,,	1·200	
2)	2·427	
Mean	1·214	

On the 16th November, 11 p.m.:—Smell Close. Carbonic acid 804 in 1,000 volumes. Dry bulb, 60°; wet bulb, 57°. Dew point, 54°·4. Elastic force of vapour, ·423. Weight of vapour in a cubic foot of air, 4·77 grains. Additional quantity required to saturate the air, 1·0 grain. Humidity, 82.

To briefly indicate how each of the observations are obtained—cubic space and measurement of areas generally by actual measurement on principles detailed on pages 104—111.

Movement of air, by an anemometer. The anemometer used for the purpose of ascertaining the velocity of currents of air, essentially consists of small very light mica sails set in a metal frame; these turn on an axis, furnished with an endless screw, which again turns a clock-work train, moving needles, which travel round properly divided circles and register the velocity. Of these anemometers there are various forms, one of the best is made by Mr. Casella, and contains improvements suggested by the late Dr. Parkes. The graduations for each instrument are obtained by actual experiment by means of machinery made for that purpose, so that the indications of all are as comparable with each other as the weight or measure of ordinary substances.

The indications are shown by means of the large dial and hand and five smaller ones as shown in the annexed plate. The whole

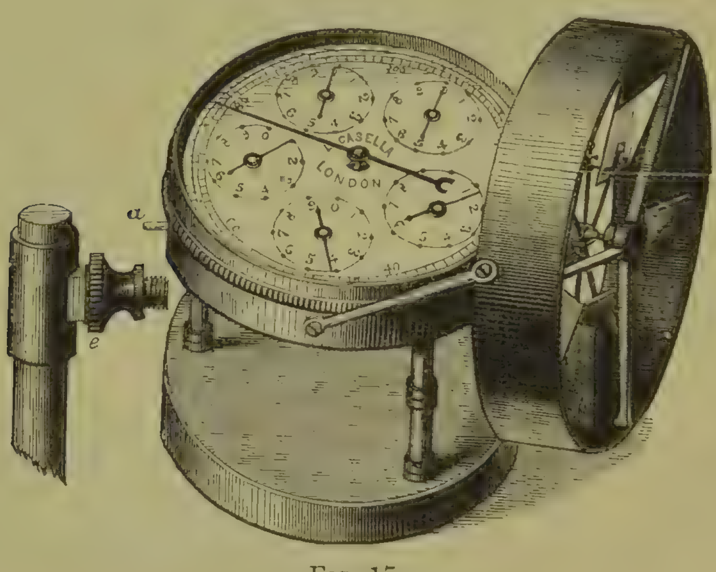

FIG. 17.

circumference of the large dial is divided into 100 parts, and represents the number of feet up to 100 traversed by the current of air. The five smaller dials are each divided into 10 parts only, one revolution of each being equal to ten of the preceding dial, and represents 1,000, 10,000, 100,000, 1,000,000, and 10,000,000, respectively. By means of the large dial, the low velocity of 50

feet per minute may be measured, and by the smaller ones continuous registration is extended up to 10,000,000 feet, or equal to 1,893 miles, being practically beyond what the most extended observations can require, whilst jewelling in the most sensitive parts insures the utmost delicacy of action. By moving the small catch *a* backwards or forwards, the work is put in or out of gear, without affecting the action of the fans; this prevents the injurious effect of stopping them suddenly, and enables the observer to begin or end his observations to a second. A small handle with universal joint accompanies the instrument, and may be screwed in at the base; by putting a stick through this, it may be raised or lowered to any required height, and used in any position. A table accompanies each instrument by means of which allowance may be made for the difference caused by inertia at high and low velocities.

Carbonic acid, by the method detailed on page 97.

The dew point, calculated from the difference between the wet and dry thermometers, or obtained directly from Dynes' hygrometer.

Elastic force of vapour, the number is found, as described at p. 129, opposite the number for the dew point.

Weight of vapour in a cubic foot of air, is obtained from Table XXIII. p. 133, opposite the dew-point temperature.

Additional weight required for complete saturation by taking out the number indicating the weight in grains of moisture to completely saturate the air at the temperature of the dry bulb, and then subtracting the weight of vapour already found from the table actually in the air, as shown by the dew-point.

Humidity from tables or by dividing the weight of vapour actually found by the weight of vapour, which, if the air was saturated, it would have contained, saturation being considered 100°. Thus, in the example on page 113—

$$\frac{\text{Weight of vapour in cubic foot of air}}{\text{,, ,, cubic foot of air when saturated}} \quad \frac{4{\cdot}77 \times 100}{5{\cdot}77} = {\cdot}826$$

SECTION III.

METEOROLOGY.

THE fundamental
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CHAPTER X.

THE BAROMETER.

(73) *Principle of the Barometer.*

THE fundamental principle underlying all barometers in which fluids are used is that the heights of two columns of two fluids are inversely as their specific gravities; air is 10,784 times lighter than mercury, therefore a column of thirty inches of mercury would support an atmosphere five miles high if it were all equally dense.

A barometer is made by filling a tube of sufficient length closed at one end, with the fluid and inverting it into a cistern of the same fluid. The liquid sinks a certain distance until it is balanced by the atmospheric pressure. Its level then remains within certain limits stationary. If the atmosphere from any cause gets lighter the barometric fluid in the tube falls, in the cistern rises, if the atmospheric pressure increases the barometric fluid rises, that in the cistern falls. The longer the column, the more obvious will be the oscillations. With the knowledge experimentally acquired that mercury of 13·59 sp. gravity will have when used as a barometric fluid a column of about thirty inches, it is easy to calculate the length of the column of any other fluid provided the specific gravity of the fluid is known; for instance glycerin has a specific gravity of 1·26 required, the length of a barometric column of glycerin.

As 1·26 the specific gravity of glycerin : 30 inches :: 13·59 the specific gravity of mercury = 323·5 inches or 27 feet.

Water would have a still longer column, alcohol longer still, ether longer than alcohol, for the lighter the liquid the longer the column.

Since a long column is far more sensitive than a short column, Physicists early turned their attention to constructing barometers with water. But water barometers are no longer made, the few which were constructed gave untrustworthy results, mainly from the effect of temperature on the aqueous vapour in the top of the tube and from other causes.

(74) *The Glycerin Barometer.*

The barometer of the future seems decidedly to be the glycerin barometer invented by Mr. Jordan, which has been now for several years in use at Kew.

The body of the instrument is formed of an ordinary metal gas tube five-eighths of an inch internal diameter, and furnished at the top with a gun metal socket in which is cemented a glass tube four feet long, inside diameter one inch; the upper end is formed in the shape of an open cup, and it has fitted into its neck a stout india-rubber stopper. The height of the fluid is observed in this tube, and read by means of brass scales placed on either side of the tube and fitted with indices and verniers, which are moved by means of milled heads placed at the bottom of the scales.

The cistern is a cylindrical vessel of copper tinned inside, five inches deep and ten inches diameter. It is fitted with a cover screwed on, and air has access through a pinhole in the cap attached to the cover; the cap has a recess packed with cotton wool, so that the air filters in dust-free. There is an arrangement by which the lower end of the tube can be for temporary purposes closed by a plug. To fill the tube with glycerin, the glycerin, warmed to 100° F., and tinted with aniline, is poured into the cistern, and air sucked out at the top by an air-pump to the full extent to which the glycerin will rise; the lower end is then stopped with the plug and the rest of the tube filled absolutely full with glycerin. The india-rubber stopper is now inserted and the lower plug withdrawn; the glycerin now sinks to about 323 inches, and bubbles of air in the course of a day or two find their way up into the vacuum. These are most conveniently removed by applying an air pressure pump to the surface of the fluid in the cistern by making a connection with the cap, the upper india-rubber stopper being of course temporarily removed. This operation may have to be

repeated; lastly, to prevent absorption of water, petroleum specially purified is poured in a layer of about an inch on the top of the glycerin in the cistern.

Glycerin has a very small coefficient of expansion, according to Reinold ·000303 for 1° F. between 32° and 212°; readings have to be corrected for temperature and reduced to sea-level. It may also be desirable to express the readings in terms of the mercurial barometer; if done by calculation it must be remembered that 323·571 inches equals 30·3 inches Kew standard; a convenient plan is to have mercury equivalents attached to the scale of the instrument.

The following is one of the well-known diagrams which appear

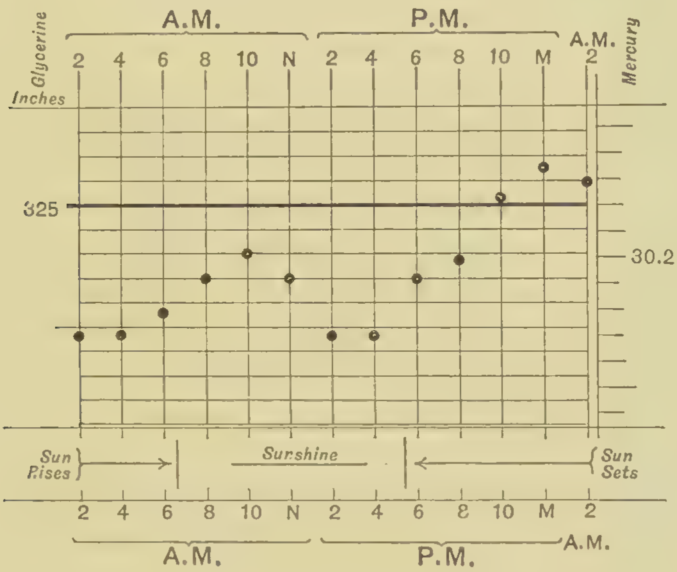

FIG. 18.

daily in the *Times*, the glycerin values on one side, the mercurial on the other.

(75) *Mercurial Barometers.*

The advantage of the mercurial over the glycerin barometer is its portability and moderate size. It is not every one who cares to have a tube over twenty-seven feet long carried through his rooms, while the length of the mercurial barometer is under three feet.

The simplest of mercurial barometers is the syphon form. A glass tube is bent in the form of a syphon, the longer limb being

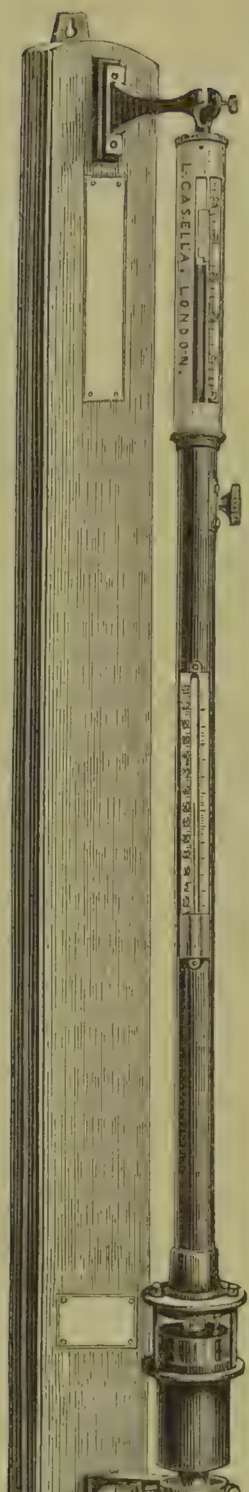

Fig. 19.

about thirty-two inches in length, the shorter eight or nine inches; to both upper and lower limbs scales are fixed, and the difference of level in the two gives the height of the barometer.

The best and most accurate form of mercurial barometer is that known as Fortin's; in this what is called the *cistern-error* is got rid of. When mercury falls in the tube the mercury in the cistern in which the tube is immersed necessarily rises, and if the mercury rises in the tube of course the mercury in the cistern falls: hence there is a constant source of error from the height of the mercury in the cistern varying. In Fortin's there is an inner cistern containing the mercury, the bottom of the cistern is of a flexible material (leather) and by means of a small screw the cistern capacity is either contracted or enlarged, and in this way the level adjusted before each observation.

The one figured (Fig. 19) was made by Mr. Casella. The mercury in the cistern is adjusted at each observation to a fixed ivory point which thus forms the zero of the scale.

The cistern is made partly of glass, to admit of the zero of the scale being visible, and the mercury is adjustable to the zero or ivory point by means of a thumb-screw acting upon the flexible base. The vernier reads to 0·002 of an inch, or, by estimation, to 0·001 inch, and is adjusted by a rack and pinion motion. In front of the barometer a thermometer is attached, in contact with the tube, with divisions etched on the stem. For facility of reading, a slab of white porcelain is placed behind the scale. The barometer is mounted in a brass frame, and suspended from a bracket at the top of a mahogany board, so as to insure perpendicularity. At the bottom of the board

is a socket, with clamping screws for steadying the barometer in a vertical position, when an observation is made. The instrument is so mounted that it can be turned at pleasure to any source of light.

(76) *Reading a Mercurial Barometer.*

The attached thermometer must first be read. Next the cistern error must be got rid of; this is done by the bottom screw, the mercury is raised or depressed until it barely touches the ivory point which, with its reflection, will then appear as a double cone. The height of the column is then taken by adjusting the lower edge of the vernier, so that it shall exactly form a tangent to the convex surface of the mercury in the tube just excluding the light from the apex when the eye is in the same plane with the back and front lower edges of the vernier. In adjusting the level in the cistern, the mercury should always be *screwed up* to the cone, and if the point of the cone is submerged the screw must be turned down until it is quite clear of the surface before the final adjustment is made. This precaution is necessary in order to preserve the same form of surface of mercury in the tube at different readings.

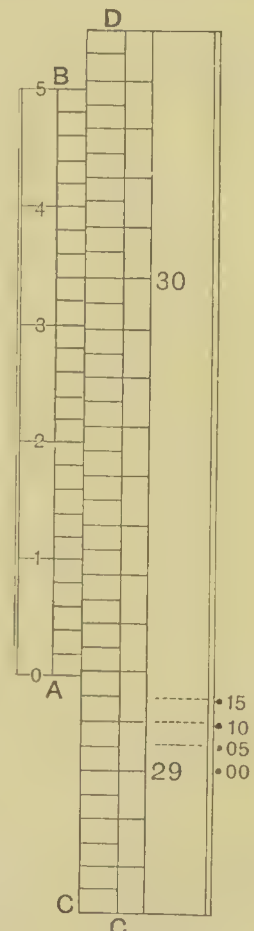

FIG. 20.

How to Read the Vernier.—By means of the annexed diagram, the use of the vernier in insuring accurate measurement is readily understood. C D represents part of the fixed scale of the barometer, and A B is the sliding scale or vernier. The scale C D is divided into inches, tenths, and half-tenths of an inch, so that each division of the scale is ·05 ; A B is made equal to 24 divisions of the scale, and is divided into 25 equal parts. It follows, therefore, that each division of the vernier is smaller than each division of the scale by the 25th part of ·05 ; which is ·002 inch. The lower edge of the vernier A, is set to the top of the barometrical column, and hence we have to find the height of A. First we read on the scale, say 29·15 ; next we look along the vernier until we find one of its lines which lies evenly with

a line of the scale. As shown in the figure, this line is the second above 3. Now each of the figures engraved on the vernier counts as hundredths, and each intermediate division counts as *two* thousandths (·002); hence the vernier shows ·034, and this added to the scale reading 29·15, gives the reading sought, 29·184.

In the Kew pattern barometers the inches on the scale are not really inches, but are so contracted as to thoroughly correct for the variation of the level of the mercury in the cistern.

In the old barometers this was effected by calculating the so-called "capacity correction;" in the Fortin barometers it is done by raising or lowering the mercury to the fiducial ivory point, and in the Observatory standard by moving the scales to the mercury.

The instructions given above for using the Fortin barometer apply equally to the Kew pattern, except that the cistern adjustment is unnecessary.

(77) *Correction of Barometer Readings.*

In order to ascertain the true pressure of the atmosphere, and to render comparable observations made in different localities, it is usual to reduce all barometric observations to what they would have been had the instrument been at the temperature of melting ice, and the barometer itself at the mean level of the sea. These corrections are fully explained, and all necessary tables are given in Marriott's *Hints to Meteorological Observers*, and in Scott's *Instructions for the Use of Meteorological Instruments*, and in many other meteorological books, but some formulæ are given below which may be useful to those who may happen to be without a set of tables or text-book when they wish to reduce their observations.

A special correction for temperature must be made in the case of barometers of the Kew pattern, a full account of which appears in the *Philosophical Magazine* for 1861.

These formulæ assume that the scale is brass, and also that the expansion of mercury is uniform for the range of temperature employed, which latter assumption, though not absolutely true, will give no appreciable error.

Barometric readings must be reduced to sea-level, and to 32 degrees of the Fahrenheit thermometer (0°C.) These are most conveniently obtained from tables, but the principle should be thoroughly understood.

There is also a correction for capillarity, and one for differences of gravity,[1] the latter depending on the latitude, that is the different distances from the centre of the earth. The two latter are neglected save in very refined observations. These corrections are simplest when the French system of millimetres is in use. For moderate elevations the following formulæ for both the English and metrical barometer are sufficiently accurate.

(*a.*) Formula for the reduction of the English barometer to the freezing point and sea-level.

$$H = h\left(1 - \frac{9\,t - 256}{100000}\right) + \frac{E}{812{\cdot}86 - 1{\cdot}945\,t}$$

Where H is the corrected reading in inches.
h is the observed reading in inches.
t is the temperature in degrees Fahrenheit.
E is the elevation of the station above the sea-level in feet.

(*b.*) Formula for the reduction of the metrical barometer to the freezing point and sea-level.

$$H = h\left(\frac{1 - t}{6196}\right) + \frac{E}{10{\cdot}54 + 0{\cdot}41}\,t$$

Where H is the corrected reading in millimetres.
h is the observed reading in millimetres.
t is temperature in degrees centigrade.
E is the elevation of the station above the sea-level in metres.

(78) *The Aneroid Barometer.*

The aneroid barometer is of special value to medical officers of health in country districts, for from its portability it may be used for the determination of heights and contours, matters which are often necessary to know, whether for the purposes of passing judgment on a drainage scheme; the initiation of a water supply

[1] The force of gravity is usually symbolised by the letter g, at Paris g = 980·94 cm, at Greenwich it equals 981·17. 30 inches or 76 cm. of mercury at Paris represent therefore a little less pressure than at Greenwich. If h equals the height of the mercurial column, d the specific gravity of mercury, the measure of the pressure of air is ghd in absolute units of force; taking the barometer to be for instance at Greenwich as 76 cm, then 981·17 × 76 × 13·596 = 1013800 grms. per square centimetre. The value of g for any latitude l and any height h in centimetres above sea-level may be found from the following formula :—

$$g = 980{\cdot}6056\,(1 - {\cdot}00257 \cos 2\,l - 1{\cdot}96h \times 10^{9}).$$

or for studying the general configuration of the district. Aneroid barometers are now made of very great accuracy, but they must be compared with the standard mercury or glycerin barometer occasionally, otherwise mistakes may occur.

An aneroid barometer is a thin metallic air-tight box, deeply corrugated to increase its elasticity, from which the air has been entirely removed: the upper and lower surfaces of the box are held in a state of tension or separation from each other by means of a strong spring; the atmosphere pressing with varying intensity on the box, the two walls respond being driven in or relaxed; this action communicates motion to smaller springs which are connected with a needle on the dial.

The diminution of pressure in measuring heights with this or any other form of barometer is not equal for equal differences of altitude, but it follows known laws, and altitude scales have been computed, taking the varying ratio between pressure and altitude into account, besides this the temperature of the air is another cause of variation, for as temperature affects air-density it also affects the ratio of pressure to altitude. Mr. Rogers Field has, however, invented an "Engineering Aneroid" (see Fig. 21) in which there is an adjustable scale for temperature.

FIG. 21.

The altitude scale adopted in this aneroid is that of the late Astronomer-Royal (which has been compared with the formulæ of Laplace, Guyot, Baily, Plantamour and other authorities, and found to give results lying between them), and as the instrument is intended for the accurate measurement of moderate altitudes, the range is purposely limited so as to give an open graduation. The adjustment for the temperature of the air is applied by shifting the scale in accordance with the figures engraved on the outside of the instrument. The rim which holds the glass should be slightly raised, so as to be free from the locking-pin, and then turned until the figures corresponding to the air temperature are opposite to the pin, when the glass should be depressed so as to re-lock it.

The process of observation is extremely simple. The first thing is to determine, either by observation or estimation, the air temperature likely to prevail during the series of observations: if this is done within 5° it will be sufficiently accurate (within about 1 per cent.). The scale must then be set to this temperature in the manner above explained. Subsequently the readings must be taken from the outer scale of feet, and the *difference* will give the difference of elevation. The following example, given by the maker, Mr. Casella, of actual observations taken between Hampstead and London will explain the proceeding:—

Temperature of 40° *and scale set accordingly.*

Journey to London:—	Feet.	
Reading at Jack Straw's Castle, Hampstead	1640	
,, ,, Horse Guards, London	1200	
Difference		440
Journey from London:—		
Reading at Horse Guards, London	1215	
,, ,, Jack Straw's Castle, Hampstead	1640	
Difference		425
		2)865
		432 feet

The true difference of altitude, according to the Ordnance levels, is 428 feet, showing an error of only four feet. The accuracy of the result will be further increased if the observations are repeated more than once, and the average of the results taken.

It should be mentioned that the above principle of adjustment can only be correctly applied to aneroids in which the graduation is nearly uniform, and therefore extreme care is taken in the selection of suitable instruments for this purpose.

(79) *Hygrometers.*

An hygrometer is an instrument for ascertaining the amount of vapour in the air. Hygrometers are either constructed on the principle of absorption, of condensation, or evaporation.

The hair hygrometer of Saussure is an example of absorption; when the air is damp the hair absorbs moisture and shrinks in size, returning to its original length when dry.

One of the most accurate and modern of hygrometers is that of Dynes, which acts on the principle of condensation (see Fig. 22). Its indications are obtained with unusual facility by means of a

little water and ice, or cold water only. This is put into the cup A, and allowed to flow gently through the small chamber D, whence it rises through a perforated diaphragm into the space above. In this space rests the bulb of a sensitive thermometer, the space being covered water-tight by a thin smooth piece of silver or black glass. By turning the tap B the water will flow

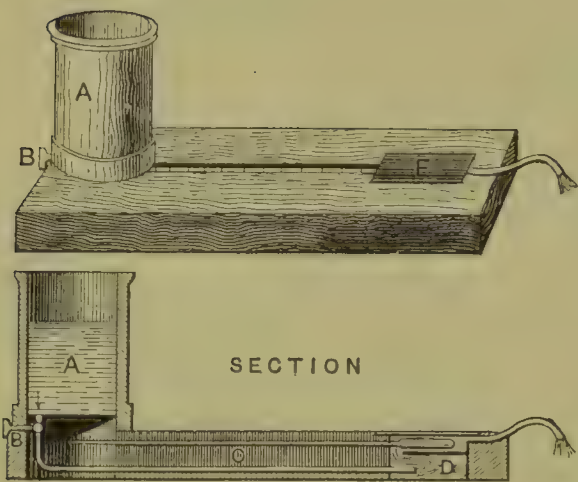

Fig. 22.

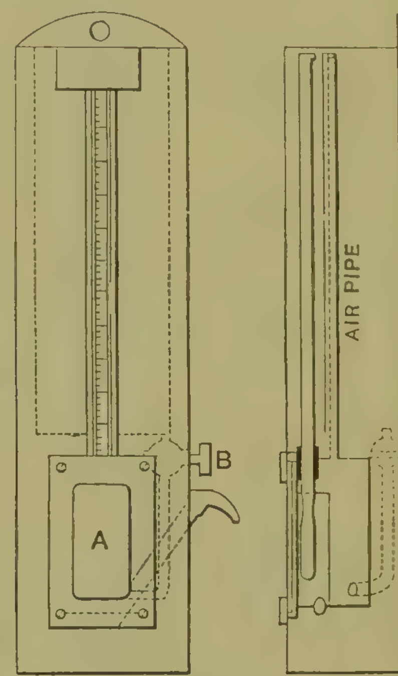

Fig. 23.

gently from the spout, as shown, thus cooling the cover; when the temperature reaches the dew-point, a strong film of vapour or dew will be visible, the temperature being shown on the graduated stem of the thermometer (Figs. 22 and 23), either horizontal or vertical form.

In the vertical form of this hygrometer (Fig. 23) ether may be employed, and a constant supply of it kept in the instrument for use whenever required.

CHAPTER XI.

THE DEW-POINT—RAINFALL—SUNSHINE—WIND.

(80) *Determination of the Dew-point.*

THE dew-point is ascertained indirectly by evaporation by means of two ordinary mercurial thermometers placed under precisely the same conditions, save that in the one "the wet bulb" has its bulb constantly kept moist by being covered with a thin piece of muslin, a thread from which dips into pure distilled water. As the water from the muslin is ever evaporating, the wet bulb always, save when the air is already saturated, gives a lower reading than the dry; and from the difference between the two readings the dew-point can be ascertained by means of tables or by calculation.

From these observations the following may be ascertained:—(1) The dew-point; (2) the elastic force of vapour, or the amount of the barometric pressure due to the vapour present in the atmosphere; (3) the quantity of vapour in a cubic foot of air; (4) the additional vapour required to saturate a cubic foot of air; (5) the relative humidity; and (6) the weight of a cubic foot of air at the pressure prevailing when the observation is made.

The formula for reduction, when the reading of the wet bulb is above 32°, is

$$F = f - \frac{d}{88} \times \frac{h}{30};$$

when the wet bulb is below 32° the formula is

$$F = f - \frac{d}{96} \times \frac{h}{30};$$

f is obtained from Regnault's determinations tabulated in Table XXI.

The dew-point is found from F by using Table XXI. reversely, and finding the temperature opposite the elastic force calculated. To borrow an example from Buchan's *Meteorology.* Suppose the dry bulb to read 50°, and the wet 45°, barom. 29 inches, then $f = {\cdot}299$ inch (from Table XXI.); $d = 50° - 45° = 5°$; and $h = 29$ inches. Hence,

$$F = {\cdot}299 - \frac{5}{88} \times \frac{29}{30} = {\cdot}244$$

from Table XXI., the temperature opposite ·244 is seen to be 39·7°, which is therefore the dew-point. A more convenient method of calculation is to use Glaisher's factors, in which, by simple multiplication of the difference between the dry and wet bulbs, and subtracting the product from temperature of the dry bulb, the dew-point is found (see Table XXII.). For instance, in the above example the dew-point would be found as follows:—

The factor opposite the dry-bulb (temperature 50°) is 2·06, the difference between the two thermometers is 5°; 2·06 × 5 = 10·3, and 10·3 – 50° = 39·7°.

The relative humidity of the air is calculated on the assumption that dry air = 0, and absolutely saturated air = 100. It is found by dividing the elastic force corresponding to the temperature of the dew-point by the elastic force corresponding to the temperature of the air, and multiplying the quotient by 100. For example, ·244 is the elastic force at 39·7°; at 50° it is ·361. Then $\frac{{\cdot}244}{{\cdot}361} \times 100 = 67{\cdot}6$, or in round numbers 68; 68 is therefore the relative humidity.

TABLE XXI.

SHOWING THE ELASTIC FORCE OF AQUEOUS VAPOUR IN INCHES OF MERCURY FROM 0° TO 80°. CALCULATED FROM REGNAULT'S DATA.

Temp.	Force of vapour.	Temp.	Force of vapour.	Temp.	Force of vapour.
°	inch.	°	inch.	°	inch.
0	·044	5	·054	10	·068
1	·046	6	·057	11	·071
2	·048	7	·060	12	·074
3	·050	8	·062	13	·078
4	·052	9	·065	14	·082

TABLE XXI. (*continued*).

Temp.	Force of vapour.	Temp.	Force of vapour.	Temp.	Force of vapour.
o	inch.	o	inch.	o	inch.
15	·086	39·7	·244	51·0	·374
16	·090	40·0	·247	51·3	·378
17	·094	40·3	·250	51·5	·381
18	·098	40·5	·252	51·7	·384
19	·103	40·7	·254	52·0	·388
20	·108	41·0	·257	52·3	·393
21	·113	41·3	·260	52·5	·396
22	·118	41·5	·262	52·7	·399
23	·123	41·7	·264	53·0	·403
24	·129	42·0	·267	53·3	·407
25	·135	42·3	·270	53·5	·410
26	·141	42·5	·272	53·7	·413
27	·147	42·7	·274	54·0	·418
28	·153	43·0	·277	54·3	·422
29	·160	43·3	·280	54·5	·425
29·5	·163	43·5	·283	54·7	·428
30·0	·167	43·7	·285	55·0	·433
30·5	·170	44·0	·288	55·5	·441
31·0	·174	44·3	·292	56·0	·449
31·5	·177	44·5	·294	56·5	·457
32·0	·181	44·7	·296	57·0	·465
32·5	·184	45·0	·299	57·5	·473
33·0	·188	45·3	·303	58·0	·482
33·5	·192	45·5	·305	59·0	·500
34·0	·196	45·7	·307	60·0	·518
34·5	·199	46·0	·311	61·0	·537
35·0	·201	46·3	·315	62·0	·556
35·3	·206	46·5	·317	63·0	·576
35·5	·208	46·7	·319	64·0	·596
35·7	·209	47·0	·323	65·0	·617
36·0	·212	47·3	·327	66·0	·639
36·3	·214	47·5	·329	67·0	·661
36·5	·216	47·7	·331	68·0	·684
36·7	·218	48 0	·335	69·0	·708
37·0	·220	48·3	·339	70·0	·733
37·3	·223	48·5	·342	71·0	·759
37·5	·225	48·7	·344	72·0	·785
37·7	·226	49·0	·348	73·0	·812
38·0	·229	49·3	·352	74·0	·840
38·3	·231	49 5	·355	75·0	·868
38·5	·233	49·7	·357	76·0	·897
38·7	·235	50·0	·361	77·0	·927
39·0	·238	50·3	·365	78·0	·958
39·3	·240	50·5	·367	79·0	·990
39·5	·242	50·7	·370	80·0	1·023

TABLE XXII.

FACTORS FOR MULTIPLYING THE EXCESS OF THE DRY BULB THERMOMETER OVER THAT OF THE WET BULB, TO FIND THE EXCESS OF THE TEMPERATURE OF THE AIR ABOVE THAT OF THE DEW-POINT.

Dry bulb thermometer.	Factor.	Dry bulb thermometer.	Factor.	Dry bulb thermometer.	Factor.
° 10	8·78	° 40	2·29	° 70	1·77
11	8·78	41	2·26	71	1·76
12	8·78	42	2·23	72	1·75
13	8·77	43	2·20	73	1·74
14	8·76	44	2·18	74	1·73
15	8·75	45	2·16	75	1·72
16	8·70	46	2·14	76	1·71
17	8·62	47	2·12	77	1·70
18	8·50	48	2·10	78	1·69
19	8·34	49	2·08	79	1·69
20	8·14	50	2·06	80	1·68
21	7·88	51	2·04	81	1·68
22	7·60	52	2·02	82	1·67
23	7·28	53	2·00	83	1·67
24	6·92	54	1·98	84	1·66
25	6·53	55	1·96	85	1·65
26	6·08	56	1·94	86	1·65
27	5·61	57	1·92	87	1·64
28	5·12	58	1·90	88	1·64
29	4·63	59	1·89	89	1·63
30	4·15	60	1·88	90	1·63
31	3·70	61	1·87	91	1·62
32	3·32	62	1·86	92	1·62
33	3·01	63	1·85	93	1·61
34	2·77	64	1·83	94	1·60
35	2·60	65	1·82	95	1·60
36	2·50	66	1·81	96	1·59
37	2·42	67	1·80	97	1·59
38	2·36	68	1·79	98	1·58
39	2·32	69	1·78	99	1·58
				100	1·57

Table XXIII.

Weight in Grains of a Cubic Foot of Vapour, under the Pressure of 30 Inches of Mercury for every Degree of Temperature from 0° to 100°. The Temperature is the Dew-Point, and the Weight of Vapour is the Weight which can be Sustained at that Temperature without becoming Visible.

Temp. F.	Weight in grains of a cubic foot of vapour.	Temp. F.	Weight in grains of a cubic foot of vapour.	Temp. F.	Weight in grains of a cubic foot of vapour.
32°	2·13	55°	4·87	78°	10·31
33	2·21	56	5·04	79	10·64
34	2·30	57	5·21	80	10·98
35	2·48	58	5·39	81	11·32
36	2·48	59	5·58	82	11·67
37	2·57	60	5·77	83	12·03
38	2·66	61	5·97	84	12·40
39	2·76	62	6·17	85	12·78
40	2·86	63	6·38	86	13·17
41	2·97	64	6·59	87	13·57
42	3·08	65	6·81	88	13·98
43	3·20	66	7·04	89	14·41
44	3·32	67	7·27	90	14·85
45	3·44	68	7·51	91	15·29
46	3·56	69	7·76	92	15·74
47	3·69	70	8·01	93	16·21
48	3·82	71	8·27	94	16·69
49	3·96	72	8·54	95	17·18
50	4·10	73	8·82	96	17·68
51	4·24	74	9·10	97	18·20
52	4·39	75	9·39	98	18·73
53	4·55	76	9·69	99	19·28
54	4·71	77	9·99	100	19·84

(81) *Measurement of Rain—Rain Gauges.*

A rain gauge may be constructed of any open vessel of known area, the rain collected being afterwards measured in a common ounce measure. A fluid ounce contains 1·733 cubic inch of water. An easy calculation will then show how much this is per square inch of surface.

Accurate observations can however only be made by having a proper rain gauge, as represented in the diagram (see Fig. 24), which is what is known as the "Meteorological Office Rain Gauge." It has a high rim to secure the more correct measurement of snow

In this is a funnel directing the rain into a graduated glass vessel, (Fig. 25), by the aid of which the rainfall is estimated directly.

Mainly through the efforts of Mr. G. J. Symons, F.R.S., the great practical importance of an accurate knowledge of the amount of rain falling in different localities has been increasingly recognized during the last twenty-five years. The general result of experiments has been to show that the size of the gauge is not very important, but that practically from 3 to 8 inches in diameter is the most expedient. In exposed positions 5-inch gauges collect rather too little; for such stations 8-inch gauges are therefore

Fig. 24.

Fig. 25.

preferable. If the orifice of a gauge be nearly level with the ground it will collect an undue amount, as the water will splash in off surrounding grass, leaves, or soil; on the other hand, if the gauge be raised above the ground, it will collect less the higher it is raised. It has therefore been decided that the orifice should in all cases be 1 foot above the surface of the ground.

Mr. Symons' rules as to placing rain gauges are as follows:—

Rules for Observers.—A rain gauge should not be set on a slope or terrace, but on a level piece of ground, at a distance from shrubs, trees, walls, and buildings—at the very least as many feet from their base as they are in height. Tall-growing flowers, vegetables, and bushes must be kept away from the gauge. If a thoroughly clear site cannot be obtained, shelter is most endurable from N.W.,

N., and E., less so from S., S.E., and W., and not at all from S.W. or N.E.

The funnel of a rain gauge must be set quite level, 1 foot above ground, and so fixed by three or four pegs that it will remain firm in spite of any gale of wind.

The gauge should be emptied regularly each day, at 9 a.m., and the amount then measured entered to the day before that of measurement.

The measurement simply consists in emptying the contents of the bottle into the glass measure, which must be held upright, and noting the number of the division to which the water rises. Each division equals one hundredth of an inch; the fifty divisions, therefore, equal half an inch—that is to say, one division should be entered as ·01; 25 as ·25; and 50, or half an inch, as ·50; of course, if there is more than that, it must be measured separately; for instance, twice full up to the 50 and once to the 6 would be

$$\begin{array}{r} \cdot 50 \\ \cdot 50 \\ \cdot 06 \\ \hline 1 \cdot 06 \end{array}$$ or one inch and six hundredths.

The amount should always be written down before the water is thrown away.

All columns should be cast up *twice*. When there is no rain, a line should be drawn rather than cyphers inserted.

When very heavy rains occur, it is desirable to measure on their termination, and enter the particulars as remarks, and it will be found a safe plan after measuring to return the water to the gauge, so that the morning registration will not be interfered with. Of course, if there is the slightest doubt as to the gauge holding all that falls, it must be emptied, the amount being *previously* written down.

In snow, melt what is caught in the funnel and measure that as rain, and select a place where the snow has not drifted, measure with a rule the average depth, and enter it in the remarks.

A fall of rain measuring the tenth of an inch in depth, corresponds to the deposit of 2,262 gallons, or about 40 hogsheads, or 10 tons weight of water per acre.

Rainy days.—In recording meteorological observations it is of value to know the number of rainy days in any particular place, the accepted definition of a rainy day is a day on which falls at least ·01 inch of rain.

(82) *Registration of Sunlight.*

In the interests of health the number of hours direct sunshine that falls on any particular locality is perhaps more important than any other single factor.

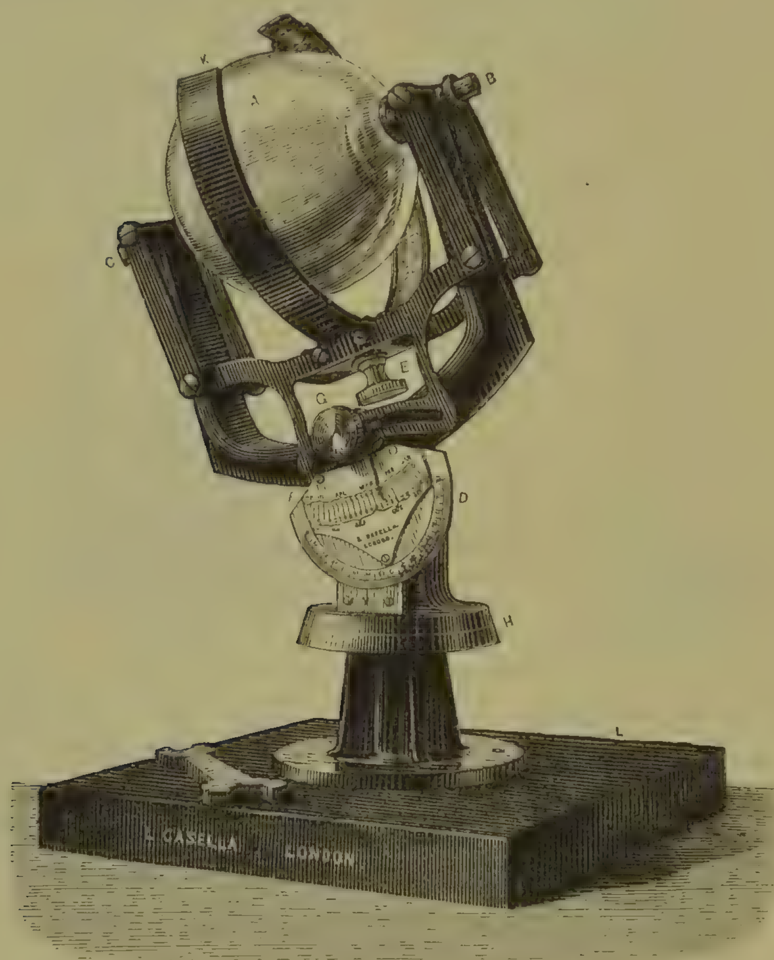

Fig. 26.

The registration of sunlight of late years has been simplified by the invention of several ingenious appliances. One of the best of these is the Whipple-Cassella universal sunshine recorder (see Fig. 26).

A strip of cardboard is arranged so that the sun's rays, concentrated to a focus by a large spherical lens, shall trace a charred line on it when they are unobscured by cloud or mist. The instrument is universal, having divided latitude and diurnal circles, and thus can be easily set for any locality and for any day in the year.

The sunshine is best expressed in percentages of the possible sunshine, if for instance the sun is above the horizon for ten hours and the record is but one hour, then the sunshine received is obviously 10 per cent.

(83) *Wind Anemometers.*

An Anemometer for the purpose of estimating currents of air has been already noticed in speaking of ventilation; such a delicate instrument as there described would not be suitable for registering the force or velocity of the wind. The public observatories use for the most part Robinson's and Osler's anemometers, the one registering the swiftness of the air current, the other the pressure.

Robinson's anemometer consists of four metallic cups screwed on to the ends of two horizontal iron rods crossing each other at right angles and supported on a vertical axis which turns freely. A train of clock work is connected with the revolving axis by means of an endless screw, and the number of revolutions is recorded on the dial.

Osler's anemometer essentially consists of a plate a foot square kept perpendicular to the wind by means of a vane; the board has attached to it a spiral spring to which an index showing the degree of pressure is attached; by a mechanical arrangement this pressure is recorded by a pencil.

The velocity of the wind can be approximately calculated from the pressure and conversely by the following formula:—

Pressure $= V^2 \times \cdot 005$ and velocity $= \sqrt{200 \times P}$.

SECTION IV.

WATER SUPPLY.

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CHAPTER XII.

SOURCES OF WATER SUPPLY.

In a few cases a water supply is obtained by distilling sea water, such as for instance in the small towns in some parts of Peru where rain never falls and where there are no other sources of supply, but leaving this quite exceptional instance, the sources of supply for the main part fall under the three following heads:—I. Rivers; II. Lakes; and III. Wells.

(84) I. *Rivers.*

The word naturally includes all running water, whether from springs or streams. The ordinary flow of rivers depends upon springs or other underground drainage, it is only in times of flood that surface waters find their way into the channel. In but very few instances is a stream pure enough to be used directly; it generally has to be stored and filtered. In the majority of instances a water supply from a river can be led into a storage reservoir without pumping, that is by gravitation alone, provided the intake is placed far enough up the river. In other instances pumping must be resorted to.

(85) II. *Wells.*

Wells are either surface, or deep wells or artesian wells.

A surface well may yield water which comes from a considerable depth, but it is generally merely rain and subsoil water mixed with more or less of the soluble matters of the soil dissolved; occasionally surface wells are very pure. In some parts of Devonshire, for example, surface wells yield water containing but two or three grains of mineral and an unweighable quantity of organic matter.

Deep wells are derived from springs. A spring is a flow of water which essentially depends upon the following conditions. A permeable stratum crops up on the surface of the ground, resting upon an impermeable stratum; rain falling upon the permeable stratum percolates through until it is stopped by the impermeable stratum. If the stratum again crops up at a lower level the spring there bursts forth, if this does not happen, the water is stored up as in a reservoir, and can be reached by sinking a well.

Wells are therefore sunk through impervious strata into pervious strata, the water in the latter being confined by impervious strata below. Imagine a sheet of india-rubber, and on the sheet a thick layer of sand, and above a layer of putty or some other doughy material, if water is now made to pass into the sand it is confined between the two layers, the under one preventing the water running away, the upper preventing evaporation; this is an illustration of most of the water-bearing stratum into which wells are sunk.

(86) *Artesian Wells.* [1]

These are tube wells often sunk to a very great depth. The most common and successful artesian wells have been sunk into the chalk.

From many of the artesian wells the water rises above the mouth in a stream, and pumping machinery is unnecessary. Thus the new La Chapelle well sunk in the Paris basin has a depth of 720 metres and the water rises 35 metres above the mouth. This well furnishes 6,000 cubic metres in 24 hours. It is even proposed to utilize this force to drive a dynamo for the production of electricity. At Ponce de Leon, Florida, the water from an artesian well drives a turbine wheel and dynamo, and by means of this motive force the hotel is lit by electricity. In other cases the water has to be pumped to the surface.

(87) III. *Lakes.*

When lakes are used as reservoirs for the supply of large towns, the enormous quantity of water drawn off might lower the water in the lake and so injure various vested rights; to obviate this, the water-level in the lake has to be raised by heightening the barrier

[1] The word "Artesian" is derived from "Artois" a place where the first Artesian well is said to have been sunk.

at its outlet, the height to which this barrier has to be raised depends wholly upon the area of the lake and the quantity likely to be drained from it. Loch Katrine, 3,000 acres in area, only required the barrier to be raised 4 feet, in order that with a maximum lowering of 7 feet, it might provide a storage of 5,687 million gallons for a supply of 50 million of gallons per day. Thirlmere, which is to supply Manchester, has an area of 350 acres, and the barrier has to be raised 50 feet in order to furnish a storage of 8,100 million gallons for a similar daily supply.

(88) *Quantity of Water per Head.*

The actual quantity per head supplied to towns varies within very wide limits. The following interesting table is given by the late Major Bolton, based upon Sir J. W. Bazalgette's figures :—

TABLE XXIV.

SHOWING CONSUMPTION PER HEAD OF THE POPULATION.

	Galls. per head.		Galls. per head.
Alexandria	18—20	Madrid	3·3
Amsterdam	11—15	Marseilles	158·4
Adelaide	50	Montreal	60
Athens	21—56	Munich	33
Baltimore	54	Naples	15·4
Barcelona	7—14	New York	60·9
Berlin	13·3	Ottawa	102·5
Bombay	20	Paris	36
Boston	73·3	Pernambuco	7·3
Brisbane	33·5	Pesth	33
Buenos Ayres	20	Philadelphia	54·15
Buda	12·5	Pietermaritzburg	44
Cairo	11	Riga	31·1
Calcutta	2·2	Rio	30
Chicago	102·5	Rome	160·38
Christiana	39·7	Rotterdam	22·45
Copenhagen	13·9	Rouen	30·8
Delhi	16	San Francisco	64·5
Dresden	14·96	St. Petersburg	21·3
Durban	2	St. Jago	5·6
Frankfort	24	Seville	7·26
Genoa	24·5—94·75	Stockholm	13·5
Hague	17·6	Stuttgart	26·4
Hamburg	45·5	Sydney	25
Hanover	15·09	Toronto	82
Hongkong	5—18	Trieste	4·4
Kurrachee	25	Valparaiso	20
Lahore	10	Venice	8
Lu Lausanne	126	Vienna	13·2—19·8
Liege	16·5—30	Washington	143
London	31·25		

The quantity required for a town supply is stated usually as follows :—

TABLE XXV.

	Gallons per day per Inhabitant.		
	Least.	Average.	Greatest.
Water required for domestic purposes . .	7	10	15
Public purposes, *i.e.* for washing streets, extinguishing fires, flushing sewers, &c. .	3	3	3
Trade and manufacturers	7	7	7
Waste about	2	2	2
Total	19	22	27

It is impossible to give a large daily supply of water to any place which has not suitable channels, such as good sewers for its removal, but provided a town is properly supplied with drains, there should be no limit to the water supply; in the middle and upper classes of houses, the general employment of baths[1] much increases the demand for water. It is the writer's opinion that no town in this climate can be considered adequately supplied unless the quantity per head amounts to at least 30 gallons, and if there are manufactories which draw upon this supply, then it must be proportionately increased.

(89) *Catchment Areas, Contour Lines, Ridge Lines.*

In taking a survey of a catchment area for the purpose of supplying a town with water, a plan is necessary showing by means of "contour lines" the undulations and general slopes of the ground, and here will be a convenient place to insert a brief account of what is meant by the terms "*contour lines,*" "*datum,*" "*ridge lines.*" In the ordnance map there are seen a number of dots usually following the course of the main roads, with figures upon them; these figures express in feet and decimals of a foot, the heights of the ground at the various places mentioned, thus B.M. 355·2 means that the particular spot is 355·2 feet above the ordnance datum, and the ordnance datum level for Great Britain, is the level of mean tide at Liverpool as ascertained by a series of observa-

[1] An ordinary full length bath will take from forty to sixty gallons of water.

tions taken by the ordnance survey in 1844; it is 8 inches below the general mean level of the ocean around our coasts. If the place indicated by any of these figures be visited there will be found a broad arrow marked on some permanent object such as a mile-stone, or a church, or a rock.

Contour lines are "lines of equal altitude," and are "what would represent the water's edge, supposing water to stand at the various levels" marked out by the figures. The contour lines marked out in the 6-inch ordnance map are drawn at every 25 feet (vertical) of elevation apart and these lines may be taken as the basis. But for the purpose of water-supply or drainage, contour lines require to be drawn closer than this; they are usually drawn for local purposes every 8 or 10 feet of elevation apart. Ridge lines are also called water-shed lines. As the name indicates, ridge lines along the whole of their course are higher than the ground immediately adjacent on each side, hence the ground slopes downwards from them at both sides.

Since all water supply comes either directly or indirectly from the rain, the amount of rain which can be utilized for the supply of a town depends upon the depth of rainfall and the catchment area.

A catchment area is also called "*catchment basin*," "*drainage area*," or gathering ground. It is in almost every case a district enclosed by a ridge line, which line is continuous, save where the water finds exit. The ridge line may, and commonly does, give off branches, and thus there are produced subsidiary or secondary catchment areas. All the details of such an area are obtained from a series of levels, and the drawing of contour lines as above described.

(90) *Rainfall in relation to Water Supply.*

The most important data respecting the depth of rainfall, are as follows:—

(1) The least annual rainfall.

(2) The mean annual rainfall.

(3) The greatest annual rainfall.

(4) The distribution of the rainfall at different seasons and especially the longest continuous drought.

(5) The greatest flood rainfall, or continuous fall of rain in a short period.

For the purposes of water supply, the most important of these are the least annual rainfall and the longest period of drought, but for drainage works, the greatest annual rainfall and the greatest flood rainfall.

The amount of water from a gathering ground may be approximated from the formula $Q = 62{\cdot}15\, A\,(\frac{4}{5}\, R - E)$ where Q is the supply in gallons daily, A the catchment area in acres, R the average annual rainfall, and E the loss from evaporation both in inches.

In constructing reservoirs, the storage capacity is calculated from the number of rainless consecutive days, likely to be experienced in any given locality. In our climate this is seldom more than a month.

(91) *General Principles of a Town Water Supply.*

A supply of water to a town should properly be at such a height that by gravitation alone the water may be cast in a jet 20 feet above the highest houses. Such a system in its most perfect character, does away with the necessity for fire engines of the ordinary type; for by the multiplication of hydrants, facilities are given to deal promptly with fires. The growing height of modern buildings, enables this system only to be adopted partially. In towns of great extent and irregular levels, care has to be taken that certain portions of the mains and branches are not exposed to excessive pressure, this is obviated by causing "*loss of head*," either by passing the water through small inlets or by the use of loaded valves.

The points to be considered in water mains for streets are that they should be made of a material that will not contaminate the water, that they be of sufficient size and strength, and that the joints be absolutely water-tight. The usual material is cast-iron, and the empirical rule as regards strength is "that the thickness of a cast iron pipe is never to be less than a mean proportional between its internal diameter and one forty-eighth of an inch."

A more accurate formula is as follows, the limit of safety being six times the working pressure

$$\frac{\text{thickness}}{\text{diameter}} = \frac{\text{greatest working pressure on feet of water}}{12{,}000}$$

The capacity of the pipes must be adapted to the greatest hourly demand for water. The length required is said to be about one mile to every 2,000 or 3,000 inhabitants.

The usual material for the service pipes is lead; it is therefore of much importance in initiating a water supply to first ascertain whether the water will act on lead.

(92) *Water Meters.*

There are two kinds of water meters, the positive and the inferential. Kennedy's and Frost's piston meters are examples of the positive kind. A piston works in a cylinder and is successively filled from the top and the bottom, and the number of strokes automatically recorded. The capacity and the piston being known the result is so many measures of water.

The inferential meter is a turbine an example of which is that known as Siemens'; the flowing water causes a turbine to revolve, and from the velocity of current as measured by the revolutions of the turbine the quantity of the water is "inferred."

(93) *Constant and Intermittent Water Supply.*

A constant water supply is a continual connection of the stored water supply of the company with the consumer's house, so that he is never destitute of water. An intermittent water supply is a supply only given at intervals; the water is turned off from the branch-pipes during most of the day, being only allowed to flow for a sufficient time to fill the cisterns.

A constant water supply demands special fittings, but only small cisterns or none at all. An intermittent water supply requires that each house shall have storage room for at least 24 hours supply.

Each system has its dangers, but there is less danger of local pollution in the case of constant than intermittent. In the intermittent system there is the danger of cistern pollution, besides, which, when the water at the main is turned off there must necessarily be left a vacuum in the branch-pipes and also in the mains, and foul gases may be drawn in. Two cases occurred in the writer's district, in which coal-gas was in this way sucked in in quantity and whenever the water was turned

on, a very large delivery of coal-gas preceded the burst of water. In these cases there were defects in the gas service pipe and the water service pipe, both were near together in the ground. Each time that the service pipe became empty coal-gas and air were drawn in.

With the constant service occasionally pipes will have to be repaired; in that case the water must be turned off from mains or branches, and suction will then result just the same as with the intermittent. In both cases *defective mains or service pipes, although running bore full,* may draw in polluting matters. It has been proved experimentally that a fluid flowing through a tube with defective joints although the tube may be bore full and at some pressure yet a vacuum may occur at the joints and any gas or liquid in contact with the joints sucked in; for instance, Mr. John Spear traced an epidemic of typhoid at Mountain Ash to the contamination of the water-main in the manner indicated.

A curious pollution of a water-main is described by Dr. Tripe in his annual report for 1887. The water from the dead end of a particular main had an offensive odour. This on investigation was proved to be caused by a large growth of weed in this portion.

(94) *Fittings for Constant Water Supply.*

In effecting the change from constant to intermittent the following are the rules with regard to fittings in force in the Metropolis:—

(1). COMMUNICATION PIPES.—Point of entry must be first approved by the company. Pipe to boundary fence should be new, or where the company allow the existing lead pipes to remain, the strength and soundness will be entirely at the risk of the consumer. Weight of pipes to be as specified in regulation. (2). Iron pipes not allowed if they are to be in contact with the ground.

Every house must have but one communication pipe.

Every house at present branched, must have its own separate "communication-pipe," except in the case of a group or block of houses or those supplied by stand pipes, the water rates of which are paid by one owner; such owner may at his option have one sufficient communication pipe for such group or block.

The connection must be made by means of sound and suitable brass screwed ferrule or stop-cock, with union, and half-inch water way.

The joints of the stop-cock and ferrule must be wiped by the consumer's plumber.

All joints must be of lead and "wiped" or plumber's joints.

No pipe is to be laid in or through drains or near gas pipes.

(2). STOP-VALVE.—A sound and suitable screw-down stop-valve, not less than half an inch, and not greater than the pipe must be fixed in the communication pipe at or near the entrance, and properly covered.

(3). CISTERNS AND BALL VALVES.—All cisterns must be above ground, properly covered, accessible for inspection and cleaning, and fitted with efficient ball valves.

Wherever there is a wash-out pipe with ground plug, or any other kind of attachment, it must be connected to a warning-pipe.

(4). Stand Pipes.—Stand pipes or small cisterns properly fitted should be substituted for butt and underground cisterns.

Owners of small tenement houses are recommended, where practicable, to fix the stand pipes in the kitchens or washhouses, whereby they will be more protected from injury by frost or mischief, and future expense will be saved in repairs.

Stand pipes must not be fixed over drains.

(5) Warning Pipes.—All waste pipes must be removed or converted into warning pipes, and so placed that the discharge of water may be readily seen by the officers of the company. Such pipes to be of lead and of the minimum weights specified in regulation 29.[1]

(6). Draw Taps.—All draw taps must be sound and suitable, and of the screw-down kind.

Draw taps of the "screw-down" kind may be fixed on the rising main to supply water for drinking purposes.

Taps over sinks ought to be of the waste-preventer kind.

(7). Stand Pipes in Courts.—All stand pipes or cocks fixed outside in courts or public places to supply groups or blocks of houses, must be of the waste-preventor kind, and protected from injury by frost, theft, or mischief.

(8). Water-Closets.—Water-closets, boilers, and urinals must be served through cisterns or service-boxes, each water-closet, cistern, or service-box to have an efficient waste preventing apparatus, limiting the flush or discharge to two gallons of water, and urinals to one gallon.

(9.) Water Closet Down Pipes.—Every "down pipe" hereafter fixed for the discharge of water into the pan or basin of a water-closet is to have an internal diameter of not less than one inch and a quarter, and if of lead, is to weigh not less than 9 lbs. to every lineal yard.

(10). Baths.—No bath to have any overflow pipe other than a warning pipe. In every bath the outlet and inlet must be distinct and unconnected, the inlet to be above the high water level, the outlet to have a water-tight plug, valve, or cock.

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[1] *Reg.* 29. All lead warning pipes and other lead pipes of which the ends are open, so that such pipes cannot remain charged with water, may be of the following minimum weights, that is to say:—

½ inch (internal diameter)	... ...	3 lbs. per yard.
¾ ,, ,,	... ...	5 ,, ,,
1 ,, ,,	... ...	7 ,, ,,

CHAPTER XIII.

THE WATER SUPPLY OF THE METROPOLIS.

(95) *The London Water Companies.*

All students of sanitary science should be acquainted with the general features of the water supply of London.[1]

London is supplied by eight companies, and the supply is controlled in common by certain general enactments, viz.:—

The Metropolis Water Acts of 1852 and 1871.

The Fire Brigade Act of 1865.

The Water Works Clauses Act of 1847.

Each company has also its special Act. The eight companies are as follows:—

(96) 1. *Kent Waterworks Company.*

This company supply:—

Deptford, Greenwich, Woolwich, Charlton, Lee, Plumstead, Eltham, Bromley, Dartford, Bexley, Erith, Chiselhurst, Mottingham, Kidbrooke, and parts of the parishes of Lewisham, Camberwell and Rotherhithe.

The water supply of the Kent Company is derived from deep chalk wells between Crayford and Deptford.

The water when viewed through a two-foot tube is of a pale blue colour; it contains less than one-tenth of a grain of organic matter per gallon, from 1·2 to 3·7 grains of common salt, from 16 to 18 grains of calcic carbonate, some salts of magnesia, potash and soda, and a small quantity of silica, the solid residue, according to Dr. Bernay's analyses, varying in different wells from 22·6 to 33·9 grains per gallon, the total hardness from 16·2° to 20·3° per gallon, and the permanent hardness from 2·8° to 7·7° per gallon.

The Company has six pumping stations and eleven covered reservoirs.

[1] For further details see Colonel Sir Francis Bolton's *London Water Supply*, from whence the account in this book has been mainly followed.

(97) 2. *The New River Company.*

This company supply :—

St. Martin-in-the-Fields ; St. Paul, Covent Garden ; St. Mary-le-Strand ; St. Clement Dane ; Savoy Precinct ; St. John the Baptist, Savoy, Strand; St. James, Westminster ; St. Anne, Soho ; Rolls Liberty ; St. Andrew, Holborn-above-Bars ; St. George-the-Martyr ; Saffron Hill ; Hatton Garden ; Ely Rents ; Ely Place ; St. Sepulchre Without ; St. Giles-in-the-Fields ; St. James and St. John, Clerkenwell ; St. Luke, Middlesex ; St. Mary, Islington ; St. Pancras ; Holy Trinity, Minories ; St. Katharine Precincts (Docks) ; The City of London ; St. Mary, Whitechapel ; Christchurch, Spitalfields ; Norton Folgate ; St. Leonard, Shoreditch ; St. John, Hackney, St. Mary, Hornsey ; St. Mary, Stoke Newington ; Highgate Hamlet ; St. Botolph, Aldgate Without ; Inner and Middle Temple ; Thavies, Staple, Barnard, Lincoln and Gray's Inns ; Great and Little Amwell ; St. Margaret ; Hoddesdon ; Wormley ; Broxbourne ; Cheshunt ; Enfield, Edmonton ; Tottenham.

And in conjunction with other companies, the New River Company supply :—

St. Martin-in-the-Fields ; St. James, Westminster ; St. Pancras ; St. Katharine Precinct ; St. Mary, Whitechapel ; Christchurch, Spitalfields ; Norton Folgate ; St. Leonard, Shoreditch ; St. John, Hackney ; St. Mary, Stoke Newington ; St. John, Hampstead ; Enfield ; Tottenham.

The New River Company took its origin in the enterprise of Sir Hugh Myddelton who, partly at his own cost, conveyed after five years hard work water in an artificial channel from the springs in the county of Hertford into the City of London.

The New River takes its rise at Chadwell Spring, about one mile beyond Ware, in Hertfordshire. It is joined at a short distance from its source by a branch cut bringing water from the river Lee. The original length of the river was forty miles, but this has been reduced to twenty-eight miles. Along its course it also receives the water pumped up by powerful machinery from at least thirteen deep chalk wells. Besides which there are a number of service and storage reservoirs.

The company supply a population of over a million living in about 147,000 houses.

The average composition of the New River water is in grains per gallon :—chlorine, 1·0 ; total oxidised nitrogen, ·33 ; carbon, ·07 ; hardness, 14°·3 ; total solids, 19·9.

(98) 3. *The East London Water Company supply in the County of Middlesex :—*

Whitechapel, Old and New Towns ; Spitalfields ; Part of Bishopsgate ; Artillery Ground ; Part of St. Botolph, Aldgate ; St. George-in-the-East ; Shadwell ; Limehouse ; Wapping ; Ratcliffe ; Bow ; Bromley ; Poplar ; Bethnal Green ; Part of Shoreditch ; Hackney ; Part of Tottenham in the county of Essex ; East and West Ham ; Low Leyton ; Walthamstow ; Wanstead ; Woodford ; Chigwell ; Loughton.

The company have three distinct sources of supply from the river Lee, intake being at Chingford ; from deep wells in the chalk at

Walthamstow and Chingford, and from the river Thames at Sunbury. The latter is used only occasionally, when the other supplies are low. The company have nine stations, a large number of reservoirs with filtering beds, &c.

The general composition of the water is very similar to that supplied by the New River Company.

(99) 4. *The Southwark and Vauxhall Company.*

This company supply water to the following:—

Barnes; Battersea; Bermondsey; Clapham; East Sheen; Ham; Kew; Mortlake; Putney; Petersham; Part of Richmond; Roehampton; Sheen; Wandsworth; Part of Wimbledon; St. Giles, Camberwell; St. Mary, Newington; St. Mary, Wimbledon; St. Mary, Lambeth; St. Mary, Rotherhithe; St. Saviour's, Southwark; St. Olave's, Southwark; St. Thomas, Southwark.

The company also, in conjunction with the Lambeth company, supply parts of the parishes of Lambeth, Newington, Camberwell, St. George, Christchurch, Bermondsey, and Clapham.

The water is derived from the Thames, from which river the company is authorized to take twenty million gallons per day.

There are two sets of works drawing supply from the Thames into subsiding reservoirs.

The upper works send water into the Battersea works, where the same is there filtered, and pumped into the London district. At the lower works the water is filtered at Hampton, and from the two sets of works the district is supplied by the company.

The total length of the mains and service pipes is about 711 miles.

The average composition of the water delivered by this company is, in grains per gallon:—chlorine, 1·0; total nitrogen, ·16; organic carbon, ·12; hardness, 14·0; total solids, 19·7.

(100) 5. *The West Middlesex Company.*

The West Middlesex Company supply the following places and parishes:—

Hampstead, conjointly with the New River Company; St. Pancras, ditto; St. Ann's, Soho, ditto; St. James, Westminster, ditto; St. Marylebone, conjointly with the Grand Junction Company; Paddington, ditto; Chiswick, ditto; Hammersmith, ditto; Kensington, ditto and Chelsea Company; Chelsea, conjointly with the Chelsea Company; St. Margaret's, Westminster, ditto; Fulham, ditto; also the suburban parishes of Willesden and Hendon.

The water supplied by the company is wholly derived from the Thames, the intake being from the Thames, above that of the Southwark and Vauxhall and Grand Junction Waterworks. The water flows direct from the river, through fine screens into the engine wells. The water thus taken in at Hampton goes to subsiding reservoirs at

Barnes, is filtered through eight filter beds having a joint area of twelve acres and from thence passes to the chief distributing station at Hammersmith. There are also large reservoirs at Kensington, Barrow Hill, and Kidderpore.

The general composition of the water is the same as that of the Vauxhall Company.

(101) 6. *The Grand Junction Company.*

This company supply water to the following places:—

Part of St. James, Westminster; part of St. George, Hanover Square; a small part of St. Marylebone; Paddington; north part of Kensington; part of Hammersmith; Chiswick; Acton; Ealing; New Brentford; Heston; Hounslow; Isleworth; Hanwell; Twickenham; Hampton; Hampton Wick; Teddington; Hampton Court; Bushey Park; Whitton; Hanworth.

The water is derived wholly from the Thames, the intake being at Hampton. The company have five stations for filtering, storing and pumping purposes at Hampton, Kew Bridge, Campden Hill, Kensington, at Kilburn, and at Ealing.

Of the 48,000 houses supplied by the company at least 30,000 are supplied by the constant water system.

(102) 7. *The Lambeth Waterworks.*

The Lambeth Waterworks supply the following places:—

Thames Ditton; Esher; Long Ditton; Kingston-upon-Thames; Maldon; Morden; Wimbledon; Merton; Mitcham; Tooting Graveney; Clapham; Wandsworth; Battersea; Streatham; Croydon; St. Mary, Newington; Camberwell; Bermondsey; St. Mary, Lambeth; St. Saviour; St. George the Martyr; Christchurch.

The intake is from the Thames three miles above Hampton Court Bridge; from this intake an underground conduit over four miles in length conveys the water through East and West Molesey and Thames Ditton to the existing works at Ditton. There is also an intake at Ditton. There are eight pumping, filtering, and storing stations, viz., at Molesey, Ditton, Kingston Hill, Brixton, Streatham, Norwood, and Rockhill.

(103) 8. *The Chelsea Company.*

The places and parishes in which the Chelsea Water Company supply water are as follows:—

St. Luke, Chelsea; part of All Saints, Fulham; part of St. Mary Abbotts, Kensington; Kensington Palace and Precincts; part of St. George, Hanover Square; part of St. James, Westminster; part of St. Martin in the Fields; St. Margaret, Westminster; St. John the Evangelist, Westminster.

The water is derived from the Thames, the intake being at Walton, on the south bank of the Thames. There are also stations at Walton and West Molesey, Surbiton, and Putney Heath.

(104) *Summary of the London Water Supply.*

The relative proportion from the various sources of supply was for the year 1884 as follows:—

From the Thames and certain chalk springs in the Thames valley about	50	parts of the whole.
From the Lee and certain chalk springs in the Lee Valley	38	" " "
From eighteen chalk wells (about eight in the north and ten in the south)	12	" " "

(105) *Purification of London Water Supply. Filter Beds.*[1]

The water supplied from the Thames to London is all submitted to the purification processes of subsidence and filtration, the filter beds of the different companies vary in detail, but are all constructed upon the same plan; for example the four filter beds of the West Middlesex Company (6 acres in total area) at Barnes have a total thickness of filtering medium of 5 feet 6 inches, consisting of 2 feet 3 inches of Thames sand, 1 foot of Barnes sand, and 2 feet 3 inches of gravel of various degrees of coarseness; beneath the filter beds there are collecting drains of 6 inches diameter; they are pierced and laid 20 feet apart.

Efficient filtration largely depends on the rate or flow of the water through the filtering medium. It is laid down as an accepted standard that the rate of filtration for the Metropolitan waters should not exceed 540 gallons per square yard of filter bed each 24 hours, or 2 gallons per square foot per hour. None of the London Companies at the present time infringe this rule, and the filtration rate in practice is slower than the above.

[1] One of the most interesting experiments on the purification of water on a large scale was made at Antwerp in 1881. The water was first passed through a layer of fine sand, and then through a filter of spongy iron mixed with gravel. This filter was however found to clog at the top rather rapidly and the iron also required somewhat frequent renewal. It was found on further experiment that the water could be purified more economically by scattering cast iron borings in the water as it flowed through horizontal revolving cylinders these cylinders were furnished with projecting plates fastened at intervals round the inside, as the cylinder revolved the iron was scooped up and discharged on reaching the top. The iron was in this process first converted into ferrous oxide, by the oxygen in the water; the ferrous oxide was next in part dissolved by the carbonic acid gas as bicarbonate, a salt very easily decomposed into ferric oxide, which finally precipitates carrying organic matter down with it, the precipitate being very easily removed by filtration through sand.

Even this simple filtration does not act entirely mechanically but in some degree destroys organic matter. The oxygen dissolved in the water and the thin film of air coating the little floating particles tend to oxidize the various debris; added to this, minute micro-organisms are ever at work disintegrating the substances upon which they feed. Hence these filters purify by mechanical means, by the aid of bacteria, by other vital processes, and by a purely chemical process of oxidation.

The upper layer of the filter beds gets from time to time clogged up, and has to be broken up and renewed.

CHAPTER XIV.

THE SCIENTIFIC EXAMINATION OF WATER.

(106) *Purity of Water.*

ABSOLUTELY pure water, consisting of a chemical union with condensation of two volumes of hydrogen and one of oxygen, is a chemical curiosity—the purest distilled water always having some slight traces of foreign matters. Pure water is, indeed, only obtained by very refined methods. That which occurs in nature invariably contains some saline and some organic matters with certain gases in solution. Whether a water is pure or impure is entirely relative, for no ordinary water is pure. What, however, the chemist and the hygienist mean by "impure water" is water which there is reasonable ground for believing may injure health.

Water may be polluted injuriously in various ways. The most direct pollution is that in which excremental matters are passed straight into the water as, for example, occurs in a stream wherever there is a floating population; it is much the same thing when sewage is conveyed into a stream: there are also the various effluent waters from factories, from mines, the dead bodies of animals, insects, leaves, the droppings from birds, and various forms of personal pollution; all these are matters more or less appreciable to the sight, but there are also those insidious forms of secret underground pollution as, for instance, the contamination of a well from a far-off cesspool or midden-heap, or from an imperfect drain.

It will also be remembered that even when the water has left a reservoir and is being conveyed within the main, chances of pollution are not exhausted. (See p. 148.)

(107) *Examination and Analysis of Water.*[1]

It need scarcely be remarked that it is not the water *per se* the analyst analyzes, but his researches are directed with the object of discovering what substances are held in solution or suspension in the water.

The medical officer of health need not be a professed analyst, but he certainly should be able to make a qualitative and quantitative analysis of such a nature as to determine the main constituents, and should also be able to interpret an analysis.

The examination falls under the following heads:

I. Examination by the Senses.—Smell, taste, and general appearance.

II. Biological.—Embracing microscopical appearances; cultivation of fungi and dormant germs; experiments on animals; experiments on fish.

III. Chemical methods.

(108) I.—*Examination by the Senses.*

Water that is evidently turbid, that possesses an odour and unpleasant taste, requires no analytical process to condemn it; such a water is unsuitable for drinking purposes. A water possessing even any one of the above bad qualities will, as a rule, on further examination be found considerably polluted.

Colour.—A 2-foot tube, the ends closed with plate glass is generally used for ascertaining the colour of water. It is only the purest water that examined in this way possesses a faint, blue tint. The great majority of drinking waters are more or less coloured with various hues of brown and green. Dr. Tidy uses for the purpose of giving a definite statement of "colour" two hollow wedges, the one filled with a blue solution, the other with a brown solution, by sliding the one wedge over the other any combination of brown and blue may be produced: the colour of the water in the 2-foot tube is thus "matched" by the wedges, and the conjoint colour expressed as the combination of so many milli-

[1] In the author's work on *Foods, their Composition and Analysis*, Lond., 1888, will be found in great detail processes for water analysis.

metres of the colours. It is found that a very close relationship between the amount of organic matter in the water and the depth of brown colour exists.

Smell.—This is best ascertained in the following manner :—Half a litre or a litre of the water is warmed to blood heat in a flask, the flask being closed with a cork or stopper, a long glass tube three-quarters of an inch in diameter is introduced, and the water sucked up once or twice so as to wet the sides of the tube thoroughly; still keeping the tube in the flask but so that its lower end is out of the water, one nostril is applied to the upper end and a prolonged inspiratory sniff is taken. In this simple way, very faint odours may be appreciated.

(109) II.—*Microscopical and Biological Methods.*

To make a microscopical examination of water it is necessary to examine the sediment which falls in scanty or copious amount according to the quality of the water. To do this, the author's tube will be found very convenient.


R
C
FIG. 27.

Its capacity is about a litre. It is in principle a big pipette, so arranged that all the sediment collects in a small glass cell or cap. The little glass cell, C (Fig. 27), is adjusted so as to close the end of the tube, and then the water is poured in and allowed to subside. At the end, say of twenty-four hours, the rod, R, is inserted so as to stopper the pipette-tube from the inside, now the cap C with its cubic centimetre of water may be removed without interfering with the main bulk. From this small concentrated bulk, drops are placed under the microscope without any preparation, others are divided up on several slides and treated with (1) dilute iodine solution, (2) drops are dried and examined for bacteria by staining with methyl violet, and (3) other drops are coloured with carmine and glycerin which has the property of staining the nuclei of cells red.

A litre of water which throws down only a little sand and unrecognisable *débris* destitute of living forms may be considered, in a microscopical sense, pure.

The matters found in a water are—

1. Lifeless Forms.

(1). *Mineral matters, e. g.*, sand, clay.

(2). *Vegetable matters.*—In all shallow waters, in rivers, and in all water which is exposed to the atmosphere, the microscopist seldom fails to find vegetable *débris* in the shape of dotted ducts, spiral vessels, parenchymatous cells, bits of cuticle with the hair still adhering, the down of seeds, and other similar matters.

(3). *Dead animal matters.*—(*a*) Purely animal, such as hairs from domestic or wild animals, striped muscular tissue, scales of moths or other lepidoptera.

(*b*) Human *débris*—human hair, epithelium.

(*c*) Manufactured matters—wool, silk, and other matters.

2. Living Forms.

(*a*) *Vegetable.*—The most common vegetable forms are confervæ, oscillatoria, volvocina, desmids, diatoms, and bacteria. All of these, with the exception of diatoms and bacteria, contain chlorophyll, and are therefore of a green colour. Water containing these green organisms must of necessity have been exposed to air and light.

(*b*) *Animal Forms.*—Neglecting various water insects and living forms which can be seen by the naked eye, such as water fleas, the most frequent moving organisms seen in water are various forms of infusoria. These are for the most part propelled by the aid of fine motile hairs called "ciliæ."

Bacteria.—These are best discovered in a water by the method of cultivation.

The method of cultivation which the writer has found simplest is as follows :—

The first step is to obtain a perfectly sterile gelatinous media. This is done as follows—a pound of any lean meat is chopped up as finely as possible, and allowed to soak in about 700 c.c. of cold water for twelve hours. At the end of that time the red, feebly-acid liquid is separated in part by decantation, and in part by filtering through a linen cloth. 100 grms. of commercial gelatin are soaked for several hours in about 300 c.c. of water, and ultimately dissolved by the aid of heat: the gelatin solution is added to

the meat infusion in a flask, a fractional portion taken and its acidity carefully determined by decinormal soda. Sufficient sodic carbonate is now added to neutralize the whole liquid, as well as about a grm. of common salt and a grm. of glucose. The flask with its contents is now heated by immersing it in boiling water for two or three hours. The albuminous portion coagulates, and the coagulum carries various insoluble matters with it. The liquid is now filtered (the filter being kept hot by a steam jacket) into several Lister flasks; the flasks are well plugged with sterile cotton wool, and then submitted for three successive days to the heat of the water bath for a couple of hours. The result is a sterile jelly solid at ordinary temperatures.

The cultivation takes place on glass plates 4 inches × 4 inches; on to these plates are cemented glass rings $\frac{1}{4}$ inch broad, $\frac{1}{4}$ inch deep, and 3·8 inches in diameter, thus forming large shallow cells. The rings are cemented on to the plates by means of the jelly itself as follows:—The rings and plates are both heated to a high temperature in a hot air oven; while still hot a few drops of the liquified jelly are dropped from the flask on to the ground surface of the ring. The ring is then applied to the plate, rotated and put face downwards under a dust-proof shade to cool and set. The water to be examined is weighed in a simple form of drop-bottle (see Fig. 28), a drop or two is placed by means of the pipette stopper on to the plate, and the bottle reweighed so as to obtain by difference the weight of the drops. The nutrient gelatin melted at a gentle heat in the flasks is now poured into the cell so as to form a layer $\frac{1}{10}$th of an inch deep. The glass cell is then put into a special chamber formed of two shallow glass dishes, the one inverted over the other; the air of the chamber is kept moist by saturating a piece of blotting paper at the bottom with a solution of mercuric chloride (1:100). After from three to five days, little dots or colonies appear in the gelatin; these are centres of development, each centre being a colony containing many thousands of individual forms. They may easily be divided by examining them under a low power into bacilli, micrococci and fungi, they may also be divided into liquifying and non-liquifying according as to whether the gelatin is liquified by their action or not. The

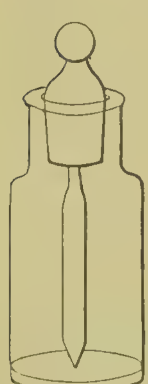

FIG. 28.

glass plate is conveniently ruled by a diamond into squares.[1] Provided the colonies are not very numerous, they are easily enumerated, but such liquids as sewage require to be largely diluted with sterile water before taking droplets for examination.

A good water seldom contains more than 1,000 colonies per gramme *when cultivated within 24 hours* after collection. If a long time elapse between the collection of a water and the cultivation, a cultivation gives but little information, for no water is absolutely sterile, and the power for increase in micro-organisms is prodigious. It is probable that a number of different kinds of micro-organisms is more important as indicative of pollution than a large number of one kind. Hitherto the method of cultivation has not been of the high value which it was first confidently anticipated it would be, for the methods employed develop common micro-organisms grown at a low temperature, and pathogenic organisms require a comparatively high temperature such as 20° to 30° Cent., the liquifying organisms in practice almost invariably prevent cultivation longer than a few days, the whole mass of gelatin becoming liquid and running together; and lastly the investigation requires much time.

It is to be hoped that future research may yet make the method practically useful; there are several researches which point out to a possibility of isolating the pathogenic from the non-pathogenic; for instance, Chantemesse and Widal have shown that trichloride of iodine in the proportion of 1 to 500 in nutrient gelatin inhibits the growth of all common micro-organisms, but the so-called typhoid bacillus will, nevertheless, grow, and by these means they were able to isolate it from other micro-organisms in excreta.[2]

(110) *Qualitative Examination of Water.*

The qualitative chemical examination of a water may be restricted to—the addition of a little "Nessler's" solution, when, if ammonia is present, there will be a greater or less yellow, amber, or brown colour—the detection of nitrites, nitrates—the reaction of the water and the presence or absence of metals.

Nitrites.—The best tests for nitrites are (1) the metaphenylene-diamine test; (2) Meldola's test; (3) the napthylamine test.

[1] There are now glass plates sold divided into squares for the purpose of counting bacteria.

[2] In the chapter treating of enteric fever will be found further details as to the possibility of isolating the bacillus of typhoid fever.

(1) *The Metaphenylenediamine Test.*—The solution is made by dissolving 5 grms. of metaphenylenediamine in 100 c.c. of water and slightly acidifying with sulphuric acid. A c.c. of the reagent added to 50 c.c. of the water strikes a pale yellow to a deep orange red, according to the quantity of nitrite present.

(2) *Meldola's Test* is a solution of para-amido-benzene-azo-dimethy-aniline in water acidified with hydrochloric acid (strength about ·02 per cent.). The reagent is added to the water to be tested, the whole acidified with sulphuric acid, warmed for 15 minutes on the water bath, and then alkalized with ammonia. If nitrites are present, the liquid becomes salmon-coloured when acid; and when alkalized with ammonia, green, with small quantities, and blue with large quantities of nitrite.

(3) *The Napthylamine Test.*—The water is first treated with sulphuric acid, acidified, and a solution of hydrochloride or sulphate of napthylamine added. A minute trace of nitrite strikes a pale pink; if much nitrite be present there is a ruby colour produced, and the solution becomes turbid from the separation of colouring matter.

The above three tests are of great delicacy, detecting one part of nitrite dissolved in several millions of water.

Detection of Nitrates.—There is no qualitative test for nitrates not shared with nitrites; in the absence of nitrites, the diphenylamine test is very convenient. Diphenylamine is dissolved in a little water by the aid of strong sulphuric acid. A few drops of the solution are added to 10 or 20 c.c. of water and double the volume of sulphuric acid. A purple blue colour denotes presence of nitrates.

Reaction of Water.—Nearly all waters are alkaline, and strike therefore a yellow colour with methyl orange, a dark red with cochineal. If acid, the colour with methyl orange is reddish orange, with cochineal a yellow tint.

Detection of Metals.

Iron.—A mixture of ferro and ferridcyanide of potash strikes a blue colour.

Lead or Copper.—A solution of cochineal strikes in a neutral or alkaline solution a feeble red having a faint blue tinge to a deep mauve blue, according to the quantity present. Hydric sulphide

gives a brown to black colour. Lead is distinguished from copper by the ferrocyanide test. A solution of potassic ferrocyanide added to a water containing a trace of copper, gives a brown colour, or if more than a trace be present, there will be a precipitate.

Zinc.—Potassic ferrocyanide added to a filtered and acidulated water containing zinc, gives a light white cloud or heavy precipitate according to the amount present.

(111) *Quantitative Chemical Examination.*

Merely qualitative examination of water is in the majority of instances insufficient, and it is necessary to know the amounts of certain constituents in water. Here will be described the simplest processes only, and it will be presumed that the reader is unacquainted with practical details. The first thing is to fit up some small room as a laboratory. To work with comfort it will be necessary to have a good sink in the room to carry away refuse liquids, and to have water and gas laid on. There should be a water-tap over the sink and water and gas laid on with taps with straight nozzles at 3 feet intervals along the working bench. The bench or table should be not more than 20 inches high, for all the apparatus is elevated by means of stands and a high bench is not so convenient for working.

The chemical apparatus required to determine chlorine, nitrogen as nitrates, free ammonia, albuminoid ammonia, oxygen consumed, sulphates, hardness, total solid residue, is as follows (the prices given are from Townsen and Mercer's list):—A balance to carry 100 grms. in each pan and to turn when loaded with half a milligrm. (£6 15*s.*); a box of grm. weights (£1 15*s.*); 1 platinum dish to contain 100 c.c. of water, (about £2 7*s.*); a copper water bath, with holes cut in it for the reception of the dishes; a set of glass and porcelain dishes; a porcelain slab; graduated flasks, either 100 c.c., 500 c.c., and 1 litre, or if preferred, 70 c.c. and 700 c.c. These flasks have a circular mark scratched on the neck, and contain the exact quantity when they are filled up to this mark. Two or three retorts, each capacious enough to hold a litre; the retorts should be tubulated and stoppered; a copper air bath, with a Page's regulator and thermometer; at least two burettes, with stand; a Liebig's condenser, with adapter and stand; Nesslerising cylinders;

retort holder, with universal joint clip; triangular stands; asbestos mill-board; wire gauze; triangles made of wire, covered with pieces of tobacco pipe for the support of platinum or porcelain dishes during ignition; one or two pairs of crucible tongs; filter paper; corks; cork-borers; distilled water; pure sulphuric acid; pure hydrochloric acid; pure potash; potassic permanganate; silver nitrate; potassic iodide; potassic chromate; sulphate of copper; zinc foil; ammonic chloride; calcic carbonate; mercuric chloride; pure sodic chloride; sodic hyposulphite; methyl orange.

(112) *Solutions Required for the Analysis.*

With these reagents and apparatus, the first thing to be done is to make up the following solutions which are arranged here in alphabetical order for facility of reference:—

Ammonium Chloride ·3146 grm., pure distilled water 1 litre, each c c. contains ·0001 grm. of ammonia, that is one-tenth of a milligramme.

Calcic Chloride Solution.—Pure calcic carbonate, ·2 grm.; dissolve in just sufficient dilute hydrochloric acid, evaporate to dryness in a platinum dish, and dissolve in a litre of water.

Copper Sulphate.—Copper sulphate, 30 grms. made up to a litre with distilled water.

Nessler Solution.—35 grms. of potassic iodide are dissolved in 100 c.c. of water, 17 grms. of pure mercuric chloride are boiled in 300 c.c. of water and then cooled. The mercuric solution is added little by little to the potassium iodide, until a permanent precipitate is formed. The liquid is now made up to a litre, with a solution of sodic hydrate (strength, 20 per cent.). Lastly, the reagent is made more sensitive by the final addition of a little more of the mercuric chloride solution, until a permanent precipitate begins to form. The solution is put on one side to deposit, and the clear liquid decanted for use.

Potassium Iodide Solution.—Potassium iodide, 1 part, dissolved in 10 parts of water.

Potassium Monochromate.—Potassium monochromate 50 grms. dissolved in a litre of water.

Potassium Permanganate.—(*a*) Alkaline; potassic permanganate 8 grms., potassium hydrate 200 grms., distilled water 1,100 c.c., the solution is boiled down to 1,000 parts, and kept in properly stoppered

bottles. (*b*) Standard volumetric for oxygen process; ·395 grms. of potassic permanganate is dissolved in a litre of water. Each c.c. contains ·0001 grm. of available oxygen.

Silver Nitrate, Standard Solution of.—4·7887 grms. of silver nitrate are dissolved in pure distilled water, and the solution made up so as to measure exactly 1 litre.

Soap, Standard Solution of.—150 parts of lead plaster are triturated in a mortar with 40 grms. of dry potassic carbonate, and made into a cream with the addition of absolute alcohol; when dissolved, filter, and by the addition of water reduce the strength to that of proof spirit. The solution of lead soap is then diluted up with proof spirit to the proper strength. The proper strength is when 14·25 c.c. are required to form a permanent lather with 50 c.c. of the calcic chloride solution.

Sodic Hyposulphite.—One part of crystallized sodic hyposulphite is dissolved in water and the solution made up to 1 litre.

(113) *The Operation of Weighing.*

One of the first things to be learnt is the operation of weighing on a delicate chemical balance. It is ascertained that the beam swings accurately by allowing the beam to swing without any load in the scales; if the beam swings to one side more than the other the student will find at the top of the beam in the centre, some simple mechanism by turning which the beam is adjusted.

To Read the Weights.—The brass weights from 100 grms. to 1 grm. create no difficulty for they have the figures marked upon them. It may be found convenient to arrange the other weights on a slip of paper in front of the balance with their values marked clearly on the paper thus—

·5* ·2 ·1 ·1 ·05* ·02 ·01 ·01 ·005* ·001*

the weights are then simply read from the blank spaces, for instance supposing the weights marked with a star are on the balance pan, the small weights taken are obviously ·556 grm. for they add up as follows:—

·5
·05
·005
·001
————
·556

The weights between 1 milligrm. (·001) and 5 milligrms. (·005) are most conveniently ascertained by working the rider; each main division equalling a milligrm.

The weights must be taken off in strict order and placed upon the scale by the aid of a pair of forceps. For instance, suppose the weight of a platinum dish should be 38·923 grms. this weight would be ascertained as follows: (1) 50 grms. weight, too heavy; (2) 20 grms. weight, not enough; (3) 10 grms. weight added to the 20, still not enough; (4) 5 grms. weight added to the weights in the pan, not enough; (6) 2 grms. weight added, not enough; (7) 1 grm. weight added, not enough; (8) 1 grm. weight, too heavy; (9) 1 grm. weight removed; (10) ·5 grm. added, not enough; (11) ·2 grm. added, not enough; (12) ·1 grm. added, not enough; (13) ·1 grm., not enough; (14) ·05, too heavy; (15) ·05 removed and ·02 grm. substituted, not enough; (16) ·01 grm. added, too heavy, and therefore removed (17) ·005 grm. added, too heavy; (20) ·005 removed and the balance closed, and the rider worked about the beam between the first and fifth division until the exact balance and swing is found with the rider on the third division.

THE ANALYSIS.

(114) *Relation between the Litre and the Gallon.*

The analyst can either operate on litres or decimal parts of a litre, or take advantage of the relation that the English grain and the gallon has to cubic centimetres. This relation is such that a milligrm. of residue from 70 c.c. is equivalent to a grain per gallon. For instance, if 70 c.c. of water on evaporation leaves ·076 grm., or, in other words, 76 milligrms., the water has a solid residue of 76 grains per gallon, or if a water contain in 70 c.c. ·005 of chlorine, that is 5 grains per gallon. If the analyst wishes to return the analysis in parts per 1,000 or per 10,000, it is then best to take 100 c.c. for the solid residue and half a litre or a litre for distillation. Parts per litre, that is parts per 1,000 are easily turned into grains per gallon by multiplying by 70; thus if a litre of water give ·0714, that is 4·99 grains per gallon for $\cdot 0714 \times 70 = 4\cdot 99$.

It will be presumed in the following that the analysis is to be expressed in parts per 1,000.

(115) *Solid Residue.*

100 c.c. of the water are placed in a platinum dish on the water-bath, evaporated to dryness, cooled and weighed; the weight of the empty dish being subtracted from the combined dish and residue of course gives the weight of the residue. After weighing, the latter may be ignited over a Bunsen burner, and it should be noticed whether there is blackening or scintillation.

(116) *Ammonia.*

Nearly all waters are alkaline and therefore the ammonia present may be simply expelled by boiling; the reaction of water is best ascertained by a solution of methyl orange; if the water is not alkaline it will be necessary to add a very small quantity of recently ignited sodic carbonate, and some chemists always add this and return the ammonia as "expelled by sodic carbonate." Half a litre or a litre of the water is placed in a tubulated retort adjusted to a Liebig's condenser, and 100 c.c. distilled over, a cubic centimetre of the Nessler solution is added to the distillate; if no ammonia at all is present, no perceptible yellow or amber tint will be noticed, but in any other case a pale yellow, amber, or dark brown colour or even a precipitate, according to the amount of ammonia present, will be produced. In these cases the maximum of colour requires a certain time, from ten minutes to a quarter of an hour, for its development. The exact tint of colour produced is to be imitated by running into 80 or 90 c.c. of pure distilled water, a carefully measured volume from a burette of the standard ammonic chloride solution, adding 1 c.c. of Nessler, and making up with pure distilled water, to the same volume of the distillate: this tint is not likely to be hit off at the first trial, either the comparison liquid is too dark or too light. It is of course open to the analyst to repeat the process by making other comparison fluids with varying quantities of the ammonic chloride solution until the right tint is obtained, but this is tedious and unnecessary. It is easier to reduce the length of the darker liquid, until it balances the lighter, and then to calculate the amount. For instance, supposing the Nesslerised distillate measuring exactly 100 c.c. is darker than the comparison liquid, which latter contains 2 c.c. of the ammonic chloride solution, but it is found that by pouring away

30 c.c. of the darker liquid, the two discs seen by looking down through the two cylinders placed side by side on a white surface such as a porcelain plaque, are exactly matched, then the following proportion sum will give the number of c.c. of ammonic chloride which the distillate is equal to—as 70 : 2 : : 100 = 2·85 c.c.

Various forms of tubes are to be bought facilitating this method, such as Nessler cylinders with taps half-way down and the tubes graduated into divisions, others have mirrors attached below and are fixed in a stand with proper arrangements for shutting off extraneous light. But for practical purposes glass cylinders of pure white glass, a white porcelain slab, and an upright narrow glass measure graduated into c.c. are quite sufficient for the purpose. Of course the number of c.c. of ammonic chloride to which the distillate is equal to gives at once the value for ammonia; for example, in the case quoted the ammonia would be equal to 2·85 c.c. × ·0001 that is ·000285 grm. of ammonia. With water containing so little ammonia as the above, the whole will practically come over in the first 100 c.c. but it is safe to distil a second quantity of 100 c.c., and to test by adding again the Nessler solution; waters which contain so large a quantity of ammonia as to give a distillate of a deep amber colour, must be distilled in less quantities than the above, for as Nesslerising is only accurate for the estimation of small quantities of ammonia, a quarter of a litre or less should be taken of waters known to be impure; or any water which by a preliminary testing with Nessler before distillation is shown to be very impure, is better dealt with by distilling a quarter of a litre over, colouring the distillate with a c.c. of methyl orange solution, and dropping into it from a burette deci-normal hydrochloric acid until it just changes colour, every c.c. of d.n. hydrochloric = ·0017 NH.

The free ammonia thus estimated, the next process is to add 50 c.c. of alkaline permanganate to the liquid in the retort and to again distil. It is well to boil up the 50 c.c. for some minutes in an open dish before adding it, and the addition of the hot alkaline solution is best poured through a funnel passed through the tubulure of the retort. The distillate is collected, about 100 c.c. at a time, and the various fractions Nesslerised until all ammonia is proved to have come over. The result is returned as "albuminoid ammonia."

(117) *Chlorine.*

Chlorine is estimated by the volumetric solution of silver nitrate. 100 c.c. of the water are either placed in a beaker resting on a white slab, or in a porcelain dish, just coloured with a solution of potassic chromate, and then the silver nitrate solution dropped in from a burette, until a reddish tinge is produced. The explanation of the test is as follows: silver chromate is a red salt, it is not formed until all the chlorides are first used up; upon its appearance, therefore, it is certain that all the chlorine is combined with silver. Each c.c. of the silver solution equals a milligrm. (·001 grm.) of chlorine, so that the number of c.c. used multiplied by ·001 equals the chlorine in 100 c.c. of water. (The reaction is made more delicate by observing the tint through a solution of chromate.)

(118) *Nitrates.*

The quickest method of estimating nitrates is by indigo-carmine. It is fairly accurate when the nitrates are in quantities—such for example as over a grain per gallon, but save with special precautions it is not a good method for the estimation of small quantities.

4 grms. of sublimed indigotin are digested for some hours with five times their weight of Nordhausen sulphuric acid, the liquid is diluted, and made up to two litres. A normal nitre solution is made by dissolving 1·011 grm. of pure potassic nitrate in one litre of water. From this solution, solutions of $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$ normal are prepared. An assay is now made by mixing, say 20 c.c. of the nitre solution with any amount of the indigo solution run from a burette deemed sufficient, in a wide-mouthed flask of 150 c.c. capacity. Oil of vitriol is run into a test-tube, the volume being equal to the united volumes of the indigo solution. The contents of the test-tube are now tipped into the mixture and the flask heated (best by a chloride of calcium bath) to 140°. If the indigo solution is insufficient, the liquid is suddenly decolourized, but in other case the liquid will continue blue. Less or more is therefore taken for the next experiment. As the amounts of the indigo solution are not proportionate exactly to the amount of nitric acid present, it is necessary to standardize by means of different

strengths of the nitre solution and the results should be all marked on the label of the bottle. To make a nitrate determination in a water, 20 c.c. of the water are taken, some indigo solution run in and an equal bulk of pure sulphuric acid, the water being kept hot the while, and the indigo dropped in from a burette, until there appears a faint blue or blue green colour. The approximate strength of the water being thus known, a second determination is made and the value of the indigo obtained from the nearest number which has been determined previously in standardizing.

Estimation of Nitrates as Ammonia.—This may be done by either making the water strongly alkaline by dissolving in it little by little metallic sodium, then distilling until free from ammonia. The retort is cooled, a small piece of aluminium foil is dropped in and the retort allowed to stand over-night. The water is again distilled, any ammonia produced is derived from the reduction of nitrates or nitrites.

Estimation by the Copper-Zinc Couple is more convenient.—Pieces of clean zinc foil, well crumpled, are immersed in a solution of copper sulphate (3 per cent.), when the zinc is coated, the liquid is poured off, the couple washed with a little distilled water, and then any convenient quantity of the water poured on to the couple and the whole allowed to stand in a warm place over-night. The water may be distilled and the ammonia estimated, subtracting what has been previously found as "free" ammonia, but in most cases the ammonia may be estimated directly by taking 10—25 c.c. of the water, diluting it up 100 c.c., and then Nesslerising direct. Here again the same correction for ammonia pre-existing will have to be made.

(119) *Hardness.*

(A) *Total Hardness.*—100 c.c. of the water to be examined are placed in a suitable bottle which can be either stoppered or corked and the standard solution of soap run in from a burette little by little; after each addition the water is violently shaken to see whether it "lathers" or not. By a very little practice the stages of the process can be detected by the ear quite as readily as by the sight; so long as the soap solution is insufficient, the shaking produces a sharp sound, whereas directly the soap has used most of the earthy salts up, the sound changes to a soft muffled note.

Sufficient soap solution has been added when a good foam or froth has been produced which remains pretty well the same for five minutes. There is a difference in the time that it takes to soften waters which contain little or no magnesian salts; and those which contain magnesian salts; the latter are decomposed with considerable slowness nor is the end reaction so sharp. Waters which take per 70 c.c. more than 16 c.c. of the soap solution require to be diluted, for the results are found not to be accurate when such comparatively strong solutions of earthy salts are treated. In these cases therefore a preliminary trial is made and then the water diluted accordingly, the best dilution being that which uses from 14 to 16 c.c. of the soap solution per 70 c.c. of the diluted water.

(B) *Permanent Hardness.*—By boiling water holding in solution carbonate of lime, the carbon dioxide, that is the gas which dissolves carbonates of lime and magnesia, is expelled, hence these carbonates are thrown down as a precipitate. The boiling should be brisk and continued until at least a third of the water has disappeared, the water is then made up to its original volume by means of distilled water, filtered and treated with soap solution just as before, the result is returned as "permanent hardness," that is hardness due to soluble salts like lime or magnesic sulphates or nitrates.

By subtracting the number of degrees of "total hardness" from the number of degrees of "permanent hardness," the degrees of "temporary hardness" are obtained.

(120) *Alkalinity.*

It is of great use to measure the alkalinity of the water. 100 c.c. of the water are placed in a Nessler cylinder, coloured yellow by means of a solution of methyl orange and deci-normal hydrochloric acid run in from a burette until the reddish hue shows that the liquid has become neutral, each c.c. of deci-normal acid is equal to ·005 grm., that is 5 milligrms. of lime carbonate, to which salt the alkalinity of water is usually due.

(121) *Sulphates.*

The quantitative determination of sulphates is very simple: a quarter of a litre or if the water should be soft, a litre of the

water, acidified with hydrochloric acid, is heated to boiling in a large beaker, and a solution of barium chloride run in until a precipitate ceases to form; the liquid is allowed to simmer for a few minutes and then put on one side to deposit, which may take some little time; the clear liquid is decanted off, the deposit boiled up in a little distilled water, collected on a filter, washed, ignited in a platinum crucible and weighed; one part of barium sulphate is equal to ·134 SO_3.

(122) *Classification of Natural Waters and the Interpretation of a Chemical Analysis.*

Great ingenuity has been displayed in the division and subdivision of waters. The simplest divisions are however the best, and it is quite sufficient to divide waters into: (1) surface waters, (2) spring waters, (3) river waters.

(1) *Surface waters* are those which are received almost direct from the heavens, that is they fall on what is termed a gathering ground and form streams, superficial wells, or lakes. Such waters are often more or less discoloured by peaty matters but contain only small amounts of dissolved salts. The waters of Dartmoor for instance often have a total residue of 5 or 6 grains per gallon, about 2 or 2·5 of which are due to lime carbonate; similarly the water of Loch Katrine supplying Glasgow only holds in solution 2·3 grains to the gallon. Such waters necessarily have very small amounts of chlorine, nitrates, and sulphates. There is another peculiarity, which is that they are largely influenced by season.

Occasionally it happens that these soft surface waters have an acid reaction, this acid reaction is said to be commonly caused by the rain washing through the sulphurous acid laden air of a town; at all events the best known instances of acid waters are derived from the north of England, and occur under conditions which are favourable to such an occurrence. An acid water will attack lead.

(2) *Springs.*—These exhibit every variety of composition, according to the geological formation in which they arise. As a rule the waters from all springs are alkaline, and they contain in solution more or less carbonates of lime and magnesia; those from the chalk are particularly hard, but organically pure.

Deep springs are very constant in their composition, and do not exhibit strongly signs of seasonal variation.

(3) *Rivers.*—Most river waters partake of a mixed character, for they are derived both from deep springs and from the rainfall flowing off the watershed through which the river runs. The composition of river water exhibits distinct seasonal variations in composition. At times of greatest rainfall, a river is most impure and at times of least rainfall most pure.

(123) *Interpretation of an Analysis.*

There is no difficulty in condemning a water which is very bad or in pronouncing a water very good; the difficulty begins when the pollution is small in amount and doubtful in character.

A water that has an offensive smell, or exhibits many moving organisms or on cultivation shows a number of colonies of diverse species, is absolutely unfit for use.

A well water sunk near a house, showing a vast difference in composition from a neighbouring well sunk at the same depth in the same soil, must be looked on with suspicion.

If a number of wells in a village are examined all of which are of nearly the same depth and in the same soil, the purest may be taken as a kind of standard by which to judge the others.

Soft peaty waters may contain a considerable amount of organic matter and may be coloured rather highly, yet if the chlorides and sulphates be low, and agree well with a sample taken from a portion of the gathering ground which from its uninhabited character must be pronounced unpolluted by sewage, such waters cannot be pronounced injurious.

In forming judgment upon a doubtful water, reliance must not be placed upon any one factor of the analysis, but the report must be based upon a valuation of all the determinations, and a careful consideration of the general tendency of evidence. It was proposed by the late Mr. Wigner to assign a definite numerical value to each part of the component parts of an analysis. This idea is a good one, the chief difficulty in its practical adoption, being that the different classes of water cannot all be measured by the same scale.

Mr. Wigner's values are as follows :—

Appearance in 2 feet tube		0
Colour blue		2
,, pale yellow		2
,, green		2
,, dark yellow		4
,, dark green		4
Suspended matter to be added to valuation of appearance—		
For traces		1
,, heavy traces		2
,, turbidity		4
Smell when heated to 100° F.—		
Vegetable matter		1
Strong peaty		2
Offensive of animal matter		4
Chlorine as chlorides	·5 gr. per gallon =	1
Phosphoric acid as phosphates—		
Traces		2
Higher quantities		from 4 to 8
Nitrogen as nitrates	·100 gr. per gallon =	1
Ammonia	·005 gr. ,, =	1
Albuminoid ammonia	·001 gr. ,, =	1
Oxygen absorbed in 15 minutes at 80° F.	·002 gr. ,, =	1
,, ,, 4 hours ,,	·010 gr. ,, =	1
Hardness before and after boiling added together	5° =	1
Total solid matter	5 grs. per gallon =	1
Heavy metals, slight traces	=	6
,, more than traces	=	12
Microscopical results—		
Vegetable debris in small quantity		4
,, ,, large ,,		8
Diatoms and bacteria in small quantity		6
,, ,, large ,,		12
Hairs and animal debris, 10 to 20 according to the quantity observed.		

Mr. Wigner considered that a water which gave values not exceeding 15 an extremely pure water. The limit of a first-class water would be about 40 ; of a second-class water, 65, and anything beyond 65 would be a third-class water.

Dr. Frankland divides waters into two sections, according to the results of a combustion :—

SECTION I.—UPLAND SURFACE WATER.

CLASS I.—Water of great organic purity, containing a portion of organic elements (organic carbon and organic nitrogen), not exceeding ·2 part in 100,000 parts of water.

CLASS II.—Water of medium purity, containing from 0·2 to 0·4 part of organic elements in 100,000.

CLASS III.—Water of doubtful purity, containing from 0·4 to 0·6 part of organic elements in 100,000.

CLASS IV.—Impure water, containing more than 0·6 part of organic elements in 100,000.

SECTION II.—WATER OTHER THAN UPLAND SURFACE.

CLASS I.—Water of great organic purity, containing a proportion of organic elements not exceeding 0·1 part in 100,000.

CLASS II.—Water of medium purity, containing from 0·1 to 0·2 part of organic elements in 100,000.

CLASS III.—Water of doubtful purity, containing from 0·2 to 0·4 part of organic elements in 100,000.

CLASS IV.—Impure water, containing upwards of 0·4 part of organic elements in 100,000.

The above mainly deals with interpretation of the organic elements of a water, but a water may be organically pure, and yet be unfit to drink because of objectionable mineral or saline constituents.

It may be at once laid down, that with regard to metals, if iron is in sufficient quantity to give a chalybeate taste, such water is not fit for a public supply. A water which contains no carbonates of the earths and has a slight acid reaction[1] will assuredly attack lead, and unless specially treated is not suitable for a public supply. A water which contains anything over 5 grains per gallon of magnesian salts, is not a good supply, and if there is choice another supply should be substituted.

(124) *Purification and Softening of Water.*

The most perfect method of purifying water is by distillation, a method which in the rainless districts of Peru and Chili is relied on to supply a considerable population, and one which is used on most of Her Majesty's ships at the present day. The other methods of purifying water are:—I. Subsidence; II. Filtration; III. Chemical treatment.

I. *Subsidence.*—Waters containing suspended matters are often very effectually cleared and rendered fit for use by being stored in reservoirs; the water being at rest, the suspended matters slowly or quickly according to their specific gravity sink to the bottom.

II. *Filtration.*—Filtration on a large scale has been already treated of. The best domestic filters are "the silicated carbon filter," "Spencer's filter," the filtering material of the "Sewage and Water Purification Company," and "Bischoff's spongy iron

[1] Dr. Tidy has made experiments which tend to show that a water containing no silica attacks lead; if subsequent research should confirm this, it will be of great importance to determine the silica in water.

filter." All these not only act as efficient strainers, but also without doubt have some not quite understood chemical action; probably in most of them each little particle is a feeble galvanic couple, and by alternate reductions and oxidations induces chemical change. The test of a good filter is that it filters slowly, that when a solution of quinine sulphate, 8 grains to the gallon, is filtered the filtrate should be destitute of bitter taste and that it retains its properties for a year, or longer.

III. *Chemical Treatment.*—For the purpose of clearing turbid waters, which will not readily deposit suspended matters, the following chemical substances are in use:—The salts of iron, especially ferrous sulphate; the salts of aluminum, especially alum and aluminate of soda; and silicate of soda.

Most turbid waters are improved by a little ferrous sulphate, the salt breaks up, and the hydrated ferrous oxide falls slowly to the bottom entangling with it more or less organic matter; treatment with alum or sodic silicate acts in a similar manner, hydrated alumina oxide or silica falling down.

Softening water also purifies it. Clarke's process is the addition of a sufficient quantity of lime to the water to unite with the free carbonic acid, the result being that the lime which has been added falls down as lime carbonate, and also that which is already in the water and has been kept in solution by the free carbonic acid. The exact amount of lime to be added can be calculated if the amount of free carbon dioxide is known, or it may be found by adding lime water of known strength from a burette to a measured portion of the water until a sample tested with silver nitrate, gives instead of a white or yellowish precipitate a brown; as soon as this brown precipitate is produced, the addition of the lime water is stopped, and then the reverse process is followed, that is the hard water is added little by little to the same water already limed until the brown colouration ceases to be produced. Clarke's process of course only deals with "temporary hardness," any hardness due to sulphates or nitrates of lime and magnesia remains, but by the addition of a sufficient quantity of caustic soda to decompose the earthy sulphates, the permanent hardness is also removed.

In Clarke's process the carbonates thrown down are in a state of very fine division, and take some time to subside. There are, however, various forms of apparatus invented which quicken the process

by rapidly removing the sediment; this is accomplished by running the water, milky from the chemical reaction, over shelves, trays, or cloths, which present a large surface to which the precipitate adheres. One of the best of these is that known as "Howatson's water softener." In this machine the precipitated carbonate adheres to a sort of webbing, the process is continuous, the milky water running in by one set of pipes, and the softened clear water running off at the top.

SECTION V.

DRAINS—SEWERS—SEWAGE DISPOSAL.

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CHAPTER XV.

DRAINS.

(125) *Legal distinction between Drains and Sewers.*

THE legal definition and distinction between "drains" and "sewers" is thus laid down by the Public Health Act, 1875 :—

"'Drain' means any drain used for the drainage of one building only, or premises within the same curtilage, and made merely for the purpose of communicating therefrom with a cesspool or other like receptacle for drainage, or with a sewer into which the drainage of two or more buildings or premises occupied by different persons is conveyed.

"'Sewer' includes sewers and drains of every description, except drains to which the word 'drain' interpreted as aforesaid applies, and except drains vested in or under the control of any authority having the management of roads, and not being a local authority under this Act."

The definition under the Metropolis Local Management Acts, 18 and 19 Vict., c. 120, sect. 250, and 25 and 26 Vict., c. 102, sect. 112, is almost the same, but with regard to "drain" the definition is extended to "and shall also include any drain for draining any group or block of houses by a combined operation under the order of any Vestry or district Board, or pursuant to the order, or with the sanction or approval of the Metropolitan Commissioners of Sewers."

It is of practical importance to thoroughly grasp these two definitions, for a *drain* will be commonly maintained by a private individual, whereas *public sewers* are vested, maintained, and repaired by the local authority. It will be seen it is neither size nor

function that makes a channel for carrying sewage a sewer or a drain, but whether it drains more than one house, if it does, and the houses so drained belong to, or are tenanted by different persons, although the drain may be only a 6-inch pipe, it is a sewer under the Act, save under the Metropolis Local Management Act, it may be the combined drainage of a block of buildings sanctioned or ordered by the authority. As may easily be conjectured from this somewhat loose definition, there are many cases in which it is doubtful whether the channel for the conveyance of sewage is a "drain" or a "sewer."

It is in some cases advantageous for a main sewer not to be absolutely water tight, but drains for houses should in all cases have sound joints; a proper drain for the carrying off of sewage is a water tight tube; on the other hand an agricultural drain, or what is called a "weeping" drain, which is sometimes put in the basements of damp houses, is a channel for the reception of the water in the soil, the subsoil water, and the joints are open and uncemented.

(126) *Brick Drains and their Defects.*

House drains are now invariably made of glazed socket pipes, or in some cases of iron pipes; the evil of square brick, or of barrel drains, the common construction of forty years ago, is well set out in the following passage from the report of the Metropolitan Sanitary Commission, 1848:—

"It is a first principle that where matter is conveyed by several small currents, if these small currents are united into another channel, of a proper form and inclination, the quicker will be the flow of the united currents, and the more powerful the sweep of any matter in suspension. From the practical observations of sewers kept free from deposit, it is manifest that very small currents suffice for the purpose, if the inclination be good, and the flow be concentrated and kept regular, for which additions of small quantities of water, at particular intervals and seasons, it is considered would be sufficient.

"The reverse of these principles generally obtains in practice in the majority of the districts of sewers. In the first place the house drains are so constructed as to spread and impede the streams, and are often kept running separately for unnecessary distances from

the sinks and house gutters. The house drains, too, receiving the water from the small 1-inch leaden pipes of kitchen sinks, are sometimes of sixty times the capacity of these pipes in the smaller houses, they are generally made of bricks in the following form (Fig. 30) :—

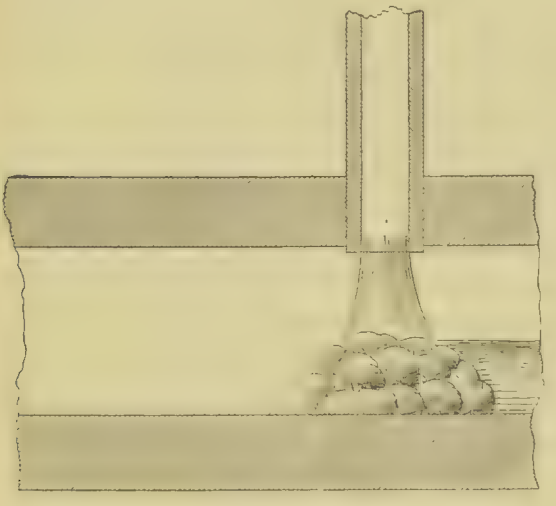

FIG. 29.

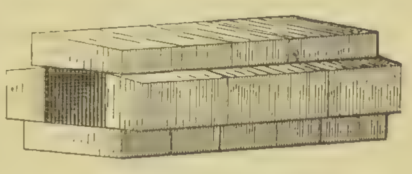

FIG. 30.

"The architects and builders generally put in barrel drains to the larger houses in the following form (Fig. 31), made of brick, with porous mortar in the upper portions :—

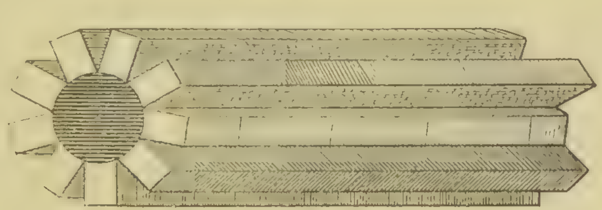

FIG. 31.

"These and the flat brick house drains are generally put in "dry" at the bottom, or without mortar, to let in the water of the land drainage, but they commonly let out at their bottoms or sides, instead of the ends, much sewer water, which permeates the foundation and site of the house, leaving the solid refuse deposited on the surface of the drain to decompose and ultimately choke it up. It is rare to find any house drain of this description without deposit. They are indeed made upon the hypothesis that they will accumulate deposit, and the construction of brick is preferred that the drains may be the more readily opened, and the

deposit from time to time removed. One of the surveyors of the Surrey and Kent sewers, Mr. Joseph Gwilt, the author of an encyclopædia of architecture, prescribes a size of drain of 5 feet square for a moderate sized mansion to enable a man to get at it to cleanse it from time to time. The Metropolitan Building Act prescribes that the least size of house drains shall be nine inches; the hypothesis being that, inasmuch as even these drains accumulate deposit, drains still larger are desirable.

"Now it is proved that whilst house drains of such size and construction as have been enforced by the Commissioners of Sewers accumulate deposit, drains of a smaller size keep perfectly clear. Thus, whilst a 12-inch drain, which is required by the Kent and Surrey, and the Tower Hamlets and the City Commissioners, accumulates deposit and generates noxious gases, a tubular drain, of nine times less capacity, or of 4 inches in diameter, or proportional to the house of from 3 to 6 inches keeps perfectly clear. Even 3-inch drains convey away the refuse from middle sized houses and keep perfectly clear, whilst the larger permeable brick drains are choked up."

Mr. Roe, the (then) surveyor of the Holborn and Finsbury division of sewers, who led the way in systematic improvements in the form of construction of main lines of sewers in the metropolis, made for the Commission experiments on the rate of flow of water through the common brick drains for houses, as compared with the rate of discharge through earthenware drains of the same capacity, and with the same run of water. The general results given are that through earthenware tubes the rates of discharge are increased to an important extent, in the smaller and more frequent forms to the extent of more than one-third. In other words, an economy of one-third the quantity of water to obtain the same result is effected by them, and the general efficiency of the drainage in ordinary runs proportionately augmented. Examples are given on the following page (Table XXVI.).

Besides the general disadvantages pointed out in the above extract from the Metropolitan Commission's report, there are certain other special evils attendant on the use of brick drains in towns supplied with a sewer system; these are the comparative ease with which rats are able to work through the brick-work and make runs, and the general tendency of brick drains to enhance

the cost of maintenance of the sewers. A brick drain in connection with a brick sewer, if at all defective at the junction between sewer and drain, soon damages the sewer, by allowing the house sewage to trickle between the sewer wall and the earth, and thus loosen the brick-work.

To summarize the above points, the chief defects of house drains when constructed of brick, are:—

(1) A tendency to deposit.

(2) The velocity of sewage in brick drains is less than in pipe drains, hence they have to be laid at a greater fall.

(3) Brick drains are almost impossible to be made tight, and except they be laid in concrete nearly always leak.

(4) Brick drains are not so easily trapped as pipe drains.

(5) They have a tendency to damage any sewer with which they are connected, and hence to make the cost of the sewer maintenance greater.

TABLE XXVI.

COMPARATIVE TIME OF RUN OF WATER THROUGH BRICK DRAINS AND GLAZED PIPES.

Inclination.	Depth of water.	Time through glazed pipes.	Time through brick drains.
Level	5 inches	38	50
2 inches in 50 feet . . .	$4\frac{1}{2}$,,	$16\frac{1}{2}$	25
$1\frac{3}{4}$,, ,, . . .	$5\frac{1}{2}$,,	19	27
$2\frac{1}{4}$,, ,, . . .	3 ,,	18	26
$1\frac{1}{2}$,, ,, . . .	$3\frac{1}{2}$,,	25	36
$3\frac{1}{4}$,, ,, . . .	4 ,,	15	22
$2\frac{3}{4}$,, ,, . . .	6 ,,	$13\frac{1}{2}$	$21\frac{1}{2}$

(127) *Varieties of Drain Pipes.*

The pipes at present in use for drains or sewers, are from 4 inches up to 18 inches, and are made of pipe clay or a mixture of fire and pipe clay; they are salt or glass glazed. They are provided with collars or sockets at the one end, which receives the spigot end of the next pipe, the joints being filled in with Portland cement; clay is often used instead of cement but the practice is to be discountenanced, for the clay is liable to wash out. There are certain patent joints, such as Stanford's, that do not require cementing, a sort of ball joint is made, and a little grease renders all tight: this

kind of joint also has the advantage that a little play is permitted without damaging the union.

It is advisable in laying drains to have at certain points and intervals pipes so constructed that the drain can be cleared or inspected. Otherwise if anything should be the matter, such as a stoppage, a pipe has to be broken. There are a multitude of ingenious devices for this purpose.

Jennings, for example, supplies a pipe in which the ordinary socket is replaced by a divided ring, the one half can at any time be removed and the pipe lifted out. Messrs Doulton make a "lidded" pipe, in which a third of the pipe can be taken off the whole length. There are also "capped" pipes to be had; in these elliptical holes are cut in the upper portion, and the openings are closed by well cemented covers. It is however not so easy to push long lengths of clearing rods through an elliptical hole of this kind, so that in the author's opinion, access pipes of the Jennings' or the "lidded" type, will be found more generally useful.

The following axioms with regard to house drains are accepted:—

All joints must be watertight.

The larger pipes receive the smaller ones, and not *vice versa*, thus 12 inch may go into 15 inch, 9 inch into 12 inch, 6 inch into 9 inch, 4 inch into 6 inch, and 2 inch into 4 inch pipes.

Never lay drain pipes underneath a house if it can be avoided.

Where one drain joins another, the line of junction should be that of a curve, or an obtuse angle. T and L shaped junctions are wrong.

When a drain changes its direction, there should be some means of inspection.

(128) *Fall of House Drains.*

The "fall" of a drain is the angle it makes with a horizontal plane, and is ascertained on the same principles as that of any sloping surface. The least fall should be one in forty-eight, that is $\frac{1}{4}$ inch to a foot; a greater fall is preferable, but as in the case of sewers, a drain may have too great a fall; for instance, a perpendicular soil-pipe entering a sewer, as in the diagram Fig. 29 is apt to produce a deposit.

Size of House Drains.—For ordinary ten-roomed houses, 4 inch pipes are usually ample, larger houses require 5 and 6 inch pipes, and large mansions may require for the main drain 9 inch pipes.

(129) *General method of House Drainage.*

The simplest case is that of a country house, provided with water-closets and having facilities for disposing the sewage upon the land.

In such a case the drain may be laid at the proper gradient mentioned above, and terminate so as to deliver into a Field's flush tank; it will in this case be unnecessary to ventilate specially the drain, but there should be syphon traps to all sink wastes, and the end of the drain should be provided with a flap-trap.

Field's flush tank is a tank with a syphon arrangement; when the liquid rises above the syphon bend the syphon comes into play, and the liquid is discharged with a rush; the reason why it is advisable even in small country houses to have an automatic flush tank to deliver the sewage upon land, is because it is found that in most cases in which the sewage is carried direct on to the channels on the land without the intervention of a tank a more or less foul deposit is formed at the outlet of the pipe.

Where dry earth closets are in use in country places, there is only the slop water to be got rid of, and it is sometimes recommended to discharge this direct into agricultural pipes laid at a suitable depth in the garden or other ground, the slop water thus escapes at various points and fertilizes the crops, but this soil pollution is only admissible in cases where it will not pollute drinking water, and even here it is preferable to use a tank, and discharge the sewage intermittently and with a rush, because it is found that the earth about the first few agricultural pipes, gets far more than its due share of sewage and there is liability to deposit.

A flap-trap should be placed on the sewer end of a drain, to prevent flow of sewage up the drain pipes when the sewer is surcharged.

No house drain should be a continuous channel for gas to flow from the sewer into the house, a syphon or disconnecting chamber being always interposed.

If a drain has to be diminished in size, it is best to use the tapering pipes made for the purpose.

The system most in vogue now in the better class of houses, is to disconnect the drain from the sewer by means of a disconnecting chamber and syphon. The disconnecting chamber is a sort of man-hole, the sides of brick, and on the floor are open earthenware channels in connection with the house drains, while on the sewer side of the chamber is a syphon; in this way, whatever odours or evil properties there may be in the house sewage, no gas from the sewer system is allowed to enter. The grating over the manhole makes a good air inlet, and if the drains of the house are also ventilated, the air should more or less continuously sweep through the system. The ventilation of the house drain should be by a pipe 4 inches in diameter, carried from the highest point of the drain above the eaves of the house, away from bedroom windows.

(130) *Traps.*

Traps are contrivances to confine sewer gas; they are either mechanical or "water seals." The simplest form of trap is what is called a flap-trap; as applied to the end of a drain the flap-trap is simply a small door, hanging from its hinge, it allows fluids to pass freely one way, but prevents more or less perfectly the passage of fluids or gases the reverse way. Provided the flap accurately fits and the hinge is in good working order, a flap-trap at the end of a drain prevents sewer gas coming into the house with any force. But as the junction of the flap cannot be made absolutely perfect, it does not prevent some small leakage of gas by diffusion; on the other hand such a trap affords a good barrier against rats, and also against the ponding back of the sewage from the sewer if the sewer should be running bore full. Other defects of the valve-trap are oxidation of the various parts, especially the hinges; the fact that when water is rushing through the drain the trap is necessarily open, and sewer gas can then pass freely.

In the Metropolis there is no systematic inspection of the traps to the mouths of the house drains; they belong to the house owner, but he has no means of personally inspecting them nor of keeping them in order. Without a doubt they should in all cases belong to the local authority, and form part of the sewer system.

Another form of mechanical trap is the "Bower's trap." The pipe to be trapped dips into a vessel containing a ball of india-rubber, which by its buoyancy seals the bottom of the pipe that

dips into the vessel of water which forms the water trap. There can be no doubt of the efficiency of the principle of this kind of trap, a familiar illustration of which is exemplified in the modern form of glass marbles closing the necks of aërated water bottles. The marble presses against a ring of india-rubber, and the greater the pressure of gas the firmer the seal. It is also exemplified in some of the best forms of mercurial pumps; for example, in the mercury pump described and figured in the author's work on foods.[1] A glass float rises on the surface of the mercury, its conical end plugs the tube, and thus there is a very effectual valve.

(131) *The Water Seal.*

The commonest form of trap is, however, the water seal, which is an application of the water lute of the chemist.

The water seal may be destroyed in different ways:—(*a*) it may be forced, as for instance when there are two traps on the same line of drain and no opening between them and hot water is poured down the drain, the air will suddenly expand, and one or both traps will be forced, the air bubbling through; (*b*) by the water in the trap evaporating, this very often happens with the bell-trap, the shallow water ring becomes dry, and then gas escapes; (*c*) "syphoning," this may happen when from any cause the pipe running full bore creates a vacuum behind the column of water, and sucks the seal out of the trap. A good example is given by Baldwin Latham in his work on sanitary engineering (see Fig. 32). S is the soil pipe open at its head; D a pipe running from the wash-hand basin B; U is a urinal. Every time the basin was used it unsealed the urinal trap, and water put down the urinal untrapped B. This mutual untrapping was cured by the insertion of the ventilating pipe. The column of water acts in these cases as if it were a solid piston; as it passes a branch it sucks the water from the syphon; the general cure for this is, as in the case cited, the ventilation of the branches; (*d*) the seal of a water trap may also be broken by the capillary action of a thread or a piece of cloth having by accident got into the syphon and hanging over the lip of the trap; the water may in this way be slowly extracted, dripping away from the end of the cloth or thread and the trap left dry. If the water in a

[1] *Foods, their Composition and Analysis.*

trap becomes saturated with foul gas, it may deliver up the gas from the house side of the trap; but this only occasionally happens.

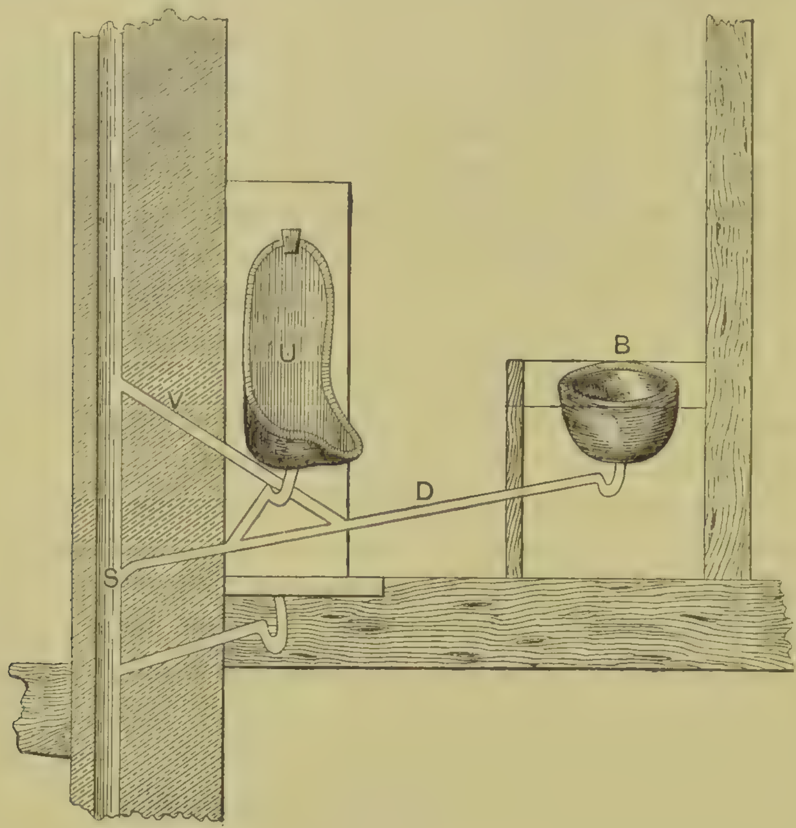

FIG. 32.

Water seal traps of approved form, and those in which the above-cited conditions of unsealing are not present, may be considered as perfect barriers to sewer gas.

(132) *Examples of Traps.*

One of the most common, and at the same time the worst traps, is what is known as the "bell trap" (see Fig. 33). It consists of two parts, a fixed iron box with a pipe connected with the drain, and a movable bell-shaped cover; the rim of the bell dips into the water around the vertical pipe. The following are the objections to the bell trap: the cover is so easily removed that as a fact it is more often off than on; when once removed sewer gas has free channel, the thin film of water forming the seal affords no adequate

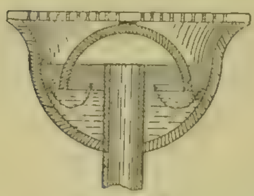

FIG. 33.

resistance to sewer gas; slight pressure forces the seal; the circular channel for the water is a natural receptacle for dirt and dust; it rapidly gets filled up, and then of course the trap is useless; lastly, from its construction, in dry weather the water rapidly evaporates, thus abolishing the seal.

An old form of trap, still used in the country, is the "dip-stone trap." It may often be seen in brick drains, placed so as to interpose a barrier between the house drain and the sewer. The drain is deepened at the spot, a piece of slate or stone placed tight across the drain but leaving a space of about 3 inches beneath. Water remains in the deepened part, forming a fairly good seal. It is also sometimes interposed in the course of a pipe drain, and in that case forms a bricked rectangular cavity. The objection to this form of trap is the liability to accumulation, and such traps are often little better than small cesspools. Dr. Corfield considers that these forms of traps may be much improved by making the ends nearest the house nearly vertical, giving the opposite one a gentle slope, and fixing the dip-stone so as to slant in the direction of the stream, and rounding off the inside with concrete, rendered in cement so that there are no angles or corners.

Stoneware syphon traps are superseding the forms mentioned. It is now a common practice to insert a stoneware gully trap between the house and the sewer, as well as to have all the yard and surface traps stoneware syphons. Experience has, however, amply proved that a syphon connected with a sewer through which all the house drainage passes gets very frequently choked up; it is therefore necessary to provide some facility for opening or cleansing the syphon. For this purpose an upright piece is made from the lowest piece of the syphon, which may be continued up to the surface of the ground. It is better still to make an opening for inspection at the house end of the syphon, so that instead of being closed with a tight lid, a grating may be placed over it and it may be used as an air inlet.

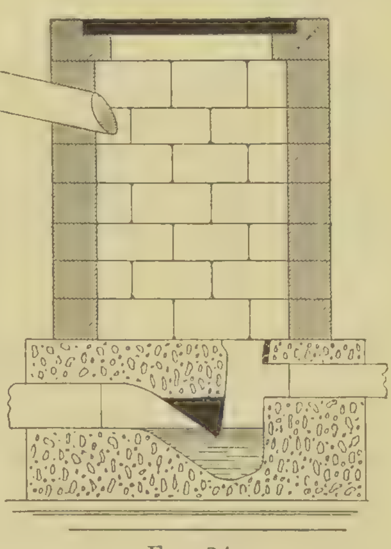

Fig. 34.

The best system of all is of course to have a manhole built of brickwork, with grooved channels at the bottom entering a syphon. In this way it is impossible for gas from the sewer to flow along the house drain into the house, and obstructions in the syphon, should they occur, are readily removed. This system was to a great extent introduced by Buchan, of Glasgow. Buchan's disconnecting chamber and trap is represented in Fig. 34.

(133) *Grease Traps.*

In sculleries of the middle class and the larger houses generally, quantities of hot liquefied fat are thrown into the drains; the fat directly it is cooled by the cold water inside the drain sets, and entangling various debris, is a potent factor in stopping a drain; hence it has been found necessary to deposit this fat in what is called a grease box or grease trap. A grease box is simply a rectangular small catchpit, connected on the one side with the scullery sink and continued on the other into the drain. Fig. 35 is a good form of grease trap; the fat floats so that by bending the exit pipe downwards, so long as the water retains its level, the escape of the grease into the drain is prevented. The grating is movable and can be taken off for the purpose of removing the accumulation of fat. Grease traps are necessary evils, but they are often productive, through inattention, of nuisance.

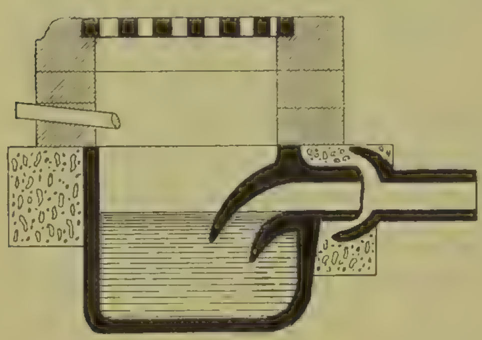

FIG. 35.

(134) *Inspection of Drainage.*

If a drain of a house enter a sewer large enough for a man to creep up, a small portion of the drain can be inspected from the sewer, by the aid of a bull's-eye lantern; at all events, it can in this way be readily ascertained whether the drain is brick or pipe, and whether it is damaging the sewer, and also whether it has a flap-trap or not.

Proceeding inside the house, all visible parts must be examined in great detail—sinks, waste-pipes, soil-pipes, and rain-water pipes,

all being methodically inspected, and notes taken of their position, apparent course, and delivery; the size and material should always be noted. In bad escapes of sewer-gas, the gas may blow up a defective pipe so strong that the hand alone will feel the current, or, if the current is not evident, the flame of a candle held above it will give signs of up or down draught. It is not enough to examine drainage in a quiescent state, it must also be examined at the time closets or waste-pipes are discharging; an escape of gas may often be made visible by sharp pulling up the closet-valve, and also by pouring a large volume of hot water down the drain. There are besides special tests—these are what are known as "the peppermint test," "the smoke test," and "the water test."

(135) *Special Drain Tests.*

The peppermint test requires two persons, one of whom takes a bottle of peppermint oil and pours about two ounces at the highest or other suitable point, and then follows it up with several buckets of boiling water, taking special precautions by shutting doors and other openings that the odour is not allowed to escape into the house, save through defects in the drain itself. The operator must of course, remain at the spot where he has applied the test, otherwise the odour remaining in his clothes will obscure all indications. His companion now examines all along the course of the drain, and if there is any smell of peppermint, it is a proof of defect. The addition of some strong ammonia to the peppermint oil is said to render the test more certain. As the principle of this test is the volatility of a strong-smelling substance, it is obvious that any volatile substance can be substituted for oil of peppermint—for instance, bisulphide of carbon, powdered iron sulphide followed by a strong acid so as to disengage sulphuretted hydrogen, light petroleum, ether, and other substances.

The smoke test is best applied at the lowest practical portion of a drain, if a special opening cannot be conveniently made, then a trap can be taken out and the sewer end of the drain blocked up by a plug. "Smoke rockets" are sold for the purpose of applying the smoke test; the rocket is lit, pushed into the drain, and the opening well covered with sacks or anything else which will keep the smoke in, a dense volume of smoke fills the drain, and bursts

through defective joints and places. There are also some very good machines in the market by which large volumes of smoke can be pumped into the drains. The water or hydraulic test is more applicable to new drains not covered in than to covered or old drains. A plug[1] is put in the lowest portion of the drain, and it is then filled with water; if the joints are not cemented an escape takes place, and the level of the water sinks to a corresponding degree.

[1] Plugs are in commerce; one of the best is an iron disc, with a deep flange in which is a thick ring of rubber. They are made of different sizes.

CHAPTER XVI.

SEWERS.

(136) *Drain-Sewers.*

WHERE the separate system is in use, as in Ely, Gloucester, Dover, and many other towns—that is where there are two sets of pipes and channels, the one for the sewage, the other for the storm and subsoil water, then the main sewers should be absolutely water-tight; and preferably constructed of socket-pipes. On the other hand, where there is no separate system, it seems best to take in the subsoil water, and therefore the mains should be constructed of brick. These latter kind of sewers Dr. Corfield calls "drain-sewers," because they fulfil a double function—they act like ordinary agricultural drain-pipes and drain away the subsoil water, and also as channels for the sewage. The chief points to be noticed in drain-sewers are the following :—

(1) They must be placed at sufficient depth to drain the cellars.

(2) They should have a fall of from 1 in 20 to 1 in 250; the latter is not always possible; the least fall by which it is known that a good sewer can be kept free from deposit is 1 in 1,000.

(3) They should be egg-shaped in section, for it is capable of proof, that an egg-shaped sewer is cheaper to construct, is stronger, gives a greater "hydraulic depth," and therefore an increased velocity, than any other form.

(4) The flow in any sewer should not be under 2 feet per second nor over $4\frac{1}{2}$ feet per second; the former will just keep a properly constructed sewer free from deposit; the latter will unnecessarily increase the maintenance expense.

Sewers should be laid in as straight lines as possible, and placed in a bed which will not be likely to sink. Concrete as a bed is often used. The gradients must be true throughout. If curves are necessary, the radius of the curve should not be less than ten times the cross-sectional diameter of the sewer.

No sewers or drains should join at right angles or directly opposite the entrance of others: two sewers joining together should always do so in the direction of the flow of the sewage; at such junction it is often advisable to form what is called a bell mouth with a ventilating shaft.

Provision must be made for easy access to sewers for flushing and clearing them, without breaking up the roadway; this is effected by side entrances, manholes, flushing chambers, and the like. The position of these manholes is of great importance, they should certainly be never placed opposite to the entrance of a public school; it is from time to time necessary for the manhole door to be opened during several hours, and during this time sewer gas freely streams through the opening. In the writer's district there have been several just complaints from this cause; these complaints have been dealt with in some instances by removing the manhole or side entrance to a more suitable spot, in others by making stringent regulations that the manhole is only to be used in certain hours.

(137) *The Flushing of Sewers.*

Sewers should be flushed periodically, whether there is any deposit or not. The simplest flushing apparatus is any kind of dam which ponds up the water, and is capable of being suddenly removed. The power of water used in this way is surprising. In an experiment with a flushing gate, 4 feet high, the quantity of water ponded back up for one flush was 26,665 feet; three flushes carried brickbats 1,300 feet; the reason for this flushing power is not alone the simple mechanical force, but also the loss of weight of solids by immersion in water, a brickbat weighing several pounds in air weighs much less in water, and hence the mechanical force added to the buoyancy force of the water moves it. Formerly the deposits in the sewers were removed by hand labour, now such deposits are only removed by hand labour when flushing fails. Hand labour is expensive; it was stated in the evidence before the

Metropolitan Sanitary Commission, that where 6,688 yards of foul deposit had been removed by flushing it was calculated that as the whole cost of removing it by hand labour would have been £2,387, while the cost of putting up the inside apparatus and flushing gate was £1,203, and the cost of men's time £644 12*s.* 7*d.*, there was thus a saving of £539.

Pipe sewers are sometimes mechanically cleansed by dragging a chain through them and afterwards well flushing.

(138) *Dead Ends of Sewers.*

No sewer should terminate in a dead end, that is to say in a *cul-de-sac*, without ventilation, it is in the dead ends that the worst forms of gas and deposits of a foul kind are apt to collect. Dead ends where possible, should be done entirely away with by connecting them with the general sewer system. In the writer's district, where the dead ends of two sewers have been some 50 feet apart, the dead ends have been connected by means of a 12 inch pipe with good results, the 12 inch pipe not carrying sewage but simply allowing the air to circulate. It is a good plan to place an automatic flush tank at dead ends, so that every 24 hours or oftener the sewer will be properly flushed out, In some instances the writer has recommended a ventilating shaft run up the nearest house, the upper end well above the eaves, and this has answered. The combination of ventilation and automatic flushing ought in all cases to keep a dead end free from danger.

(139) *The Size of Sewers. The Separate System.*

When we come to the "separate system"—that is where the sewers only carry diluted sewage, and the storm water is so far as practicable kept out of the sewers—in this case the main sewers may be of pipes properly jointed and of very moderate size. It will give a good illustration of the large area a comparatively small pipe will drain if reference be made to an old experiment of importance in the early history of drainage. The Metropolitan Commission of Sewers initiated experiments by placing pipes within the large sewers of the metropolis. Mr. Hale laid in the sewer running through Upper George Street from the Edgware Road to Manchester Street where it falls into the Scholars' Pond sewer, a 12 inch pipe drain, 560 feet long, and by proper appliances com-

pelled the sewage that would otherwise have flowed into the Upper George Street sewer, a sewer 5 feet 6 inches by 3 feet 6 inches, to flow through this pipe; the area thus drained was equal to nearly 44 acres of houses. During ninety-six hours of rain the pipe sewer was never more than half full, and it ran bore full on only one occasion for a brief period during an exceptional storm. It was also shown in the same series of experiments that the water flowing through a pipe of the kind possessed great mechanical power.

"On one occasion," said Mr. Hale, "I had the sewer in Upper George Street cleaned out immediately below the pipe, and then caused a quantity of deposit, consisting of sand, pieces of bricks, stones, mud, &c., to be put in the head of the pipe; the consequence was the whole of the matter passed clear through the pipe (560 feet long), and much of it deposited some distance from the end, on the bottom of the old sewer. When the pipe was flowing nearly half full, two pieces of brick, one weighing $1\frac{3}{4}$ lb. and the other 1 lb. 13 oz., were impelled by the force of the water through the whole length of pipe and struck the legs of the man at one end of the pipe with considerable force. A live rat was also washed out with great violence through the pipe and struck the legs of a man with such force as proved the rat had no control over its own motion."[1]

One of the first towns that used the separate system was Slough; a system of pipe drains was laid slightly above the level of the old deep sewers. About $8\frac{1}{2}$ miles of pipe sewers, varying from 9 inches to 15 in diameter, were laid, 1,200 yards of the outfall sewer being cast iron, 15 inches in diameter, jointed with lead and gasket. The subsoil water is kept out of the pipes as much as possible and goes with rain water along the old channels. Besides Slough, Reading, Oxford, Halstead and a few other places in this country have adopted the separate system; in America, Memphis on the Mississippi, and Pullman near Chicago, are notable examples of separate sewerage.

(140) *The Shape and Construction of Sewers.*

Small sewers made of glazed pipe from 6 inches to 18 inches in diameter are circular, and there is little or no benefit in making

[1] *Report of the General Board of Health on the Water Supply of the Metropolis*, p. 186.

these sizes any other form; the pipes are made in short lengths and are usually jointed by passing the end or spigot into the socket or faucet of the next, the spigot end of course is laid in *direction of the flow*, that is down hill. In certain patent joints such as Stanford's no cement is necessary; in the ordinary pipes, a ring of gasket or tarred hemp is often forced in the space filled with cement. Larger sewers are built in the eggshaped section shown in the diagrams—

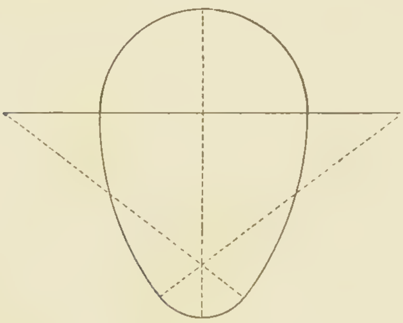

Fig. 36.

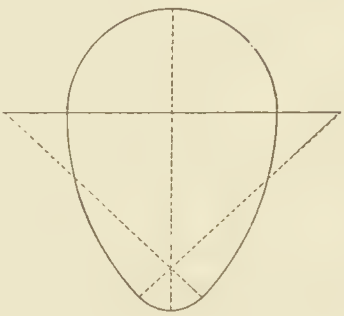

Fig. 37.

Fig. 36 is the old form, Fig. 37 is the new form; the latter has a sharper invert. The advantage of this form is that in dry weather a narrower channel is left for the small stream of sewage, and hence deposit is less likely to occur.

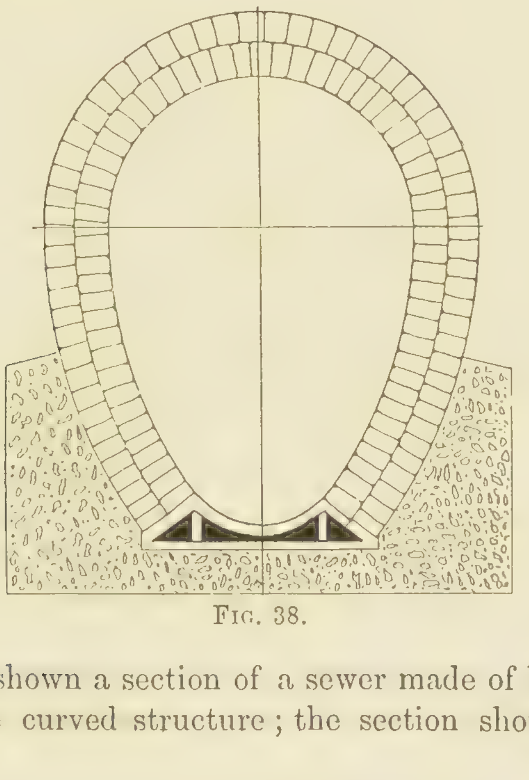

Fig. 38.

In Fig. 38 is shown a section of a sewer made of bricks moulded so as to suit the curved structure; the section shows two courses

of brick with an invert of glazed earthenware, the whole imbedded in a concrete setting.

Sewers are sometimes made wholly of concrete, the composition of the concrete being five to seven of sand and gravel or broken stone to one of Portland cement. A mould is first formed, the concrete run round, and when the concrete has set the mould is removed.

(141) *Capacity of Sewers.*

It has been already described that the capacity of the London sewers which convey the sewage to the outfall is calculated on the assumption that the sewage averages 31¼ gallons per head, and that they will also dispose of ¼ inch of rainfall. In sewering the town of Dantzic, in which the geological formation is chiefly sand, and the district flat, Mr. Baldwin Latham provided for a ¼ inch of rainfall every twenty-four hours, and 6 cubic feet of diluted sewage. No fixed rule can be given, because the water supply of various towns is so different in quantity and the geological formation is different. In places having a very impervious soil, sewers will have to be larger than in the more pervious strata. The average sewage of Birmingham is 50 gallons a head, of Cardiff 66, of Croydon 76, of Plymouth 66. All these are water-closet towns. On the other hand, Preston with a small number of water-closets only produces liquid sewage at the average rate of 24 gallons per head. It is however accepted that speaking generally a main drain-sewer should be constructed on the assumption that there will be 5 cubic feet (31¼ gallons) of sewage per head to be dealt with in the twenty-four hours, and a certain proportion of rain, depending on locality and area. The careful observations carried on at various meteorological stations and tabulated by Mr. Symons, F.R.S., give valuable rainfall data for every district in the British Islands, and it will be useful to remember that 1 inch of rain is equal to 3,630 cubic feet, or 22,622 gallons per acre.

The size of sewers vary so much that it is evident engineers have in practice applied no general principle; a drain-sewer will take sewage, subsoil water, and storm water: the amount of the subsoil water will vary in different localities; the sewage is mainly dependent in its volume on the water supply used or wasted, and the storm water of course varies very much; it is however generally admitted that a main drain-sewer intended to receive all the sewage of a

thickly populated square quarter of a mile, with a water supply of 20 gallons a head, if the average rainfall be equally distributed throughout the year, need have no larger area than 4 square feet, but that since storms must be considered, then double that quantity, namely 8 square feet of sectional area will be sufficient.

(142) *Steep Gradients.*

Special arrangements have often to be made where, from the conformation of the ground, steep gradients are a necessity; the usual way is to make a tumbling bay, the sewer delivering from above having a flap valve, the lower sewer being disconnected from the upper by means of a manhole; in this way there can be no pressure of gas, and the flap will keep any sudden rush of wind back; this is called "ramping" a sewer.

Difficulties are often met with in laying sewers from the kind of soil in which they are laid; for instance, in loose sandy soil the subsoil water often gets into the pipes before the cement is set, and the cement is in this manner washed away; the remedies proposed are either the use of cast iron pipes, or the use of a subsoil drain and pipe rest (manufactured by Messrs. Brooke and Sons, Huddersfield), this drain is in the form of the letter U; it is laid and jointed at the bottom of the trench like an ordinary pipe sewer This has the effect of draining away and therefore lowering the subsoil water, upon this subsoil drain the true sewer is laid, and it rests on a good foundation undisturbed by water or sand.

(143) *Inverted Syphons.*

Sewage has sometimes to be conveyed along the bed of the river; in such cases it is usually carried by an inverted syphon, constructed of iron pipes. The town of Dantzic, intersected by navigable channels and surrounded with fortification ditches over which no permanent work can be carried, necessitated the use of syphons there as an integral part of the sewer system, which was designed by Mr. Baldwin Latham; and in Mr. Latham's work on sanitary engineering these syphons and the various modifications of them are very clearly described.

It is not improbable that the sewage of the south side of the metropolis, now discharging at Crossness will have to be brought over to the north side, if so, this will be effected by a syphon carried on or beneath the Thames bed.

(144) *Storage Sewage Reservoirs.*

In those towns which discharge their sewage into the sea it is necessary to provide either a sufficient storage reservoir, to pond up the sewage during the time in which otherwise it would be tide locked, or to construct a tank sewer, which is practically a longitudinal reservoir; many engineers prefer to make a tank sewer—that is a very capacious sewer at the lowest practical level—rather than a covered reservoir, and it certainly seems that the tank sewer can be flushed and cleansed easier than a storage tank. In all these cases there must be special ventilating arrangements and efficient traps to prevent the sewer gases becoming a nuisance.

(145) *Road Gullies.*

Road gullies connected with the sewers, are of two kinds, viz., those which are intended to pass everything into the sewers, and those intended to intercept mud, sand, and the detritus of the roads generally. The former are to be found only in towns where the sewers have abundant fall and flushing water; in most towns the mud must be intercepted. This is accomplished by making a catch-pit below the point of overflow into the sewers of considerable depth and size, and removing the deposit from time to time; Fig. 39 is a diagram of an ordinary road gully.

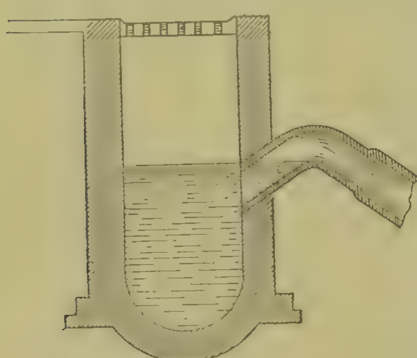

FIG. 39.

(146) *Ventilation of Sewers.*

In the metropolis this is almost entirely effected by direct openings into the sewer at frequent intervals along the centre of the roadway: these openings are never offensive along the great main arteries of sewage where there is an ample air current in the sewers themselves, but on the other hand, in certain positions where the sewers are somewhat flat, in the proximity of dead ends and under other local conditions, the sewer openings are a cause of danger and offence.

Charcoal boxes have been tried, various ingeniously arranged trays of charcoal being placed in sewer ventilators and the sewer

gas passing through the boxes has to some extent been deodorized, but on the other hand a serious mechanical impediment to the diffusion of the sewer gas into the open air is in this method introduced, besides which the charcoal soon gets useless and frequent renewal is necessary. For these reasons charcoal boxes are condemned.

The Metropolitan Board of Works, a year or two ago, recommended a strip of flannel to be hung in the sewer ventilating shaft and a jar containing a concentrated solution of sulphurous acid gas (SO_2) hung over the flannel; by carefully adjusting the stopcock of the jar, the solution dropped upon the flannel keeping it always moist and filling the shaft with sulphurous acid gas. The writer has seen this tried, and with attention it may be made to act fairly well.

A better plan is disinfection of the sewer air by Reeves' apparatus. In this ingenious invention an apparatus in shape and appearance like a filter is placed over the ventilating hole; this has two chambers, the upper one is filled with strong sulphuric acid, the lower with dry potassic permanganate or sodic permanganate; the sodic permanganate chamber is connected with a water supply and the cock is so regulated that a small stream of water washes through the permanganate, the solution escaping on to a splash plate below the apparatus; on to this same splash plate is delivered the sulphuric acid, the result of the reaction being permanganic acid, free oxygen, and sulphur dioxide. The sewer air passes through this atmosphere and a strongly disinfecting liquid enters

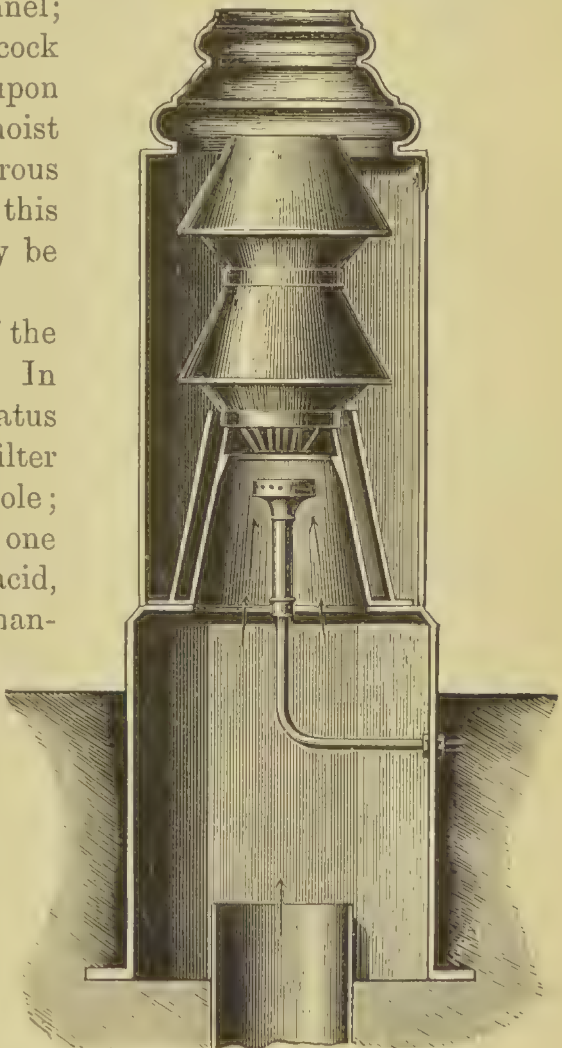

FIG. 40.

the sewer. The writer has investigated carefully this apparatus, and it is certainly effectual when in perfect working order, but requires attention.

Another method which is on its trial is Keeling's patent sewer gas exhauster and destructor; as shown in the diagram (Fig. 40), a large burner is placed within the shaft, and the arrangement is such that the sewer gas either passes through flame or other surfaces brought to a high state of heat. The claim of the inventors is that it carbonises any organic matters which the sewer gas may contain.

(147) *The Outfall of Sewers.*

The outfall of an inland sewer should be protected by a flap-valve, otherwise winds are liable, should they blow in the right direction, to sweep any sewer gas back towards the town; the position of the outfall should of course be such as not to create a nuisance. An outfall should never deliver direct below the surface of a river, save in cases where there is ample fall, otherwise the sewage is more or less locked up in the sewers. The position of an outfall delivering sewage into the sea requires to be placed so that it is under water at all periods of the tide, that it does not impede navigation, that it does not deliver the sewage so that the ebb tide carries it in front of the town, and lastly, that it is not placed in such a position that the sewage is ultimately deposited on the shore of the town. All this requires often prolonged and special study, by means of floats and other appliances on the spot, of the various tides, currents, eddies and the effects of particular winds. Sea outfalls are almost always constructed with proper valves or sluices to prevent back currents—the inflowing of the sea up the sewers.

CHAPTER XVII.

THE SEWERAGE OF THE METROPOLIS.

(148) *Interception.*

EVERY student of practical hygiene should make himself acquainted with the main features of the drainage of the metropolis, not simply on account of the magnitude of the work, nor the interests involved, but because it is at the present time the finest example of the important principle of "INTERCEPTION."

The principle of interception is this, that where there is a small longitudinal fall, and comparatively great lateral falls, and moreover the town to be drained is of considerable size, it is more advantageous to intercept the sewage of the higher zones by a special channel, called "an intercepting sewer." In this way a town is divided up into small and manageable areas.

In sea-side places interception is specially advantageous, for the lower levels are tide-locked for many hours of the day, while if an intercepting sewer carry the sewage from the higher levels to some distant point, there is no interruption of the flow from the portion of the town thus drained.

Nevertheless it cannot be said that these considerations had as much weight with the designers of the metropolitan system as the stinking state of the river Thames, the whole drainage at one time emptying at different points close along the shores of the great city itself, until huge intercepting sewers carried it elsewhere at a safer distance into the same river.

(149) *Size of the main London Sewers.*

The general history of the various commissions, schemes, and legislation on metropolitan sewerage will be found in the *First*

Report on Metropolitan Sewage Discharge of the Royal Commission, London, 1884, to which the reader may be referred.

The designers of the London main drainage, although recognizing the many advantages of a separate system for sewage and for rainfall, were compelled to undertake the problem of removing rainfall and sewage in one system, which, at all events, would have the advantage of using the rain and storm waters to effect the flushing out of the sewers. The principle upon which the size of the main sewers was constructed is thus given by Sir Joseph Bazalgette :—

"It appeared from tables of rainfall that there were only from 14 to 21 days in the year on which the rainfall exceeded the rate of a quarter of an inch in 24 hours; therefore we said, if we can divert the sewage from the river (within the metropolis) in dry weather altogether on all those days, excepting the 14 to 21, according to the season (a very wet season has been 30 days), we shall sufficiently divert the sewage from the river to make it clear."

The average amount of sewage per head was calculated to be 31¼ gallons, and in another part of his evidence Sir Joseph Bazalgette said: "We take the sewage at so many gallons per head, we take the maximum flow at double that quantity, and then we take a quarter of an inch of rain running off added to that, and taking the populations and the areas, we arrive at each point at the quantity to be intercepted."

(150) *General Principle of the Metropolitan Sewer System.*

The general principle of the metropolitan main drainage system is that of *interception.*

According to the natural hydrographical features of the district, the portion of the Thames basin on which the metropolis stands is drained by transverse streams flowing into the river on each side; and the sewers, which have been formed from time to time to effect the artificial drainage, have been made to follow the lines of these streams.

In order, therefore, to prevent these sewers from discharging into the river, the principle has been adopted of *intercepting* them by lines of conduits lying nearly at right angles to them, *i.e.* in the same general direction as the course of the river, but inclining

towards it. These conduits fall in an easterly direction, and are continued down to points on the banks of the river below London, where the sewage, intercepted and carried off by them, is discharged.

In such of these intercepting conduits as are at sufficient altitude, the sewage flows away by gravitation. But as many parts of the metropolis lie so low as to render this impossible, the contents of the intercepting conduits there have to be pumped up by steam power, in order to raise them to the necessary level of discharge.

The entire system is naturally separated into two great divisions, lying on the north and south of the river respectively.

(151) *Northern Interception.* (See map.)

On the north side there are three great lines of interception:—

1. A line called the Northern High Level Sewer, which, beginning in the north-west at Hampstead and Highgate, passing by Hackney, descending by Stratford, and crossing over the river Lea near Bow, abuts upon the Thames at Barking Creek. This conduit acts entirely by gravitation.

2. A line at a lower level called the Northern Middle Level Sewer, which begins in the west at Kensal Green, passes through Oxford Street, Clerkenwell, and Bethnal Green, and joins the Northern High Level Sewer near Bow. This conduit also works entirely by gravitation.

3. A line at a still lower level called the Northern Low Level Sewer. It begins in the extreme west at Chiswick, and passes through Chelsea, near the bank of the river, as far as the Grosvenor Road, Pimlico. Here, near the Victoria Railway Bridge, its contents are pumped into another conduit lying slightly higher, which runs along the northern Thames embankment, and near the river to the Tower, then striking off to the north-east through Stepney to Abbey Mills, near Stratford, where the contents are again pumped up to the level of the Northern High and Middle Level Sewers.

From this point the whole of the northern drainage flows through the Northern Outfall Sewer to the Thames; this outfall sewer is formed of three parallel conduits, which take the contents of the three sewers, but can be made to communicate when necessary to equalize the flow.

(152) *Southern Interception.* (See map.)

On the south side of the river there are two great lines of interception—

1. A line called the Southern High Level Sewer, which begins at Balham and passes through Clapham, Brixton, Camberwell, and New Cross, crosses under Deptford Creek by iron syphon pipes, and continues through Greenwich, Woolwich, and Plumstead Marshes to a pumping station on the right bank of the river at Crossness. The sewage reaches that point by gravitation.

2. A line called the Southern Low Level Sewer. It begins in the extreme south-west at Putney, and passes through Wandsworth, Battersea, Vauxhall, Kennington, Peckham, and New Cross, to a pumping station on the Ravensbourne, near Deptford, where the contents are pumped into the Southern Outfall Sewer.

At a certain point near Nine Elms there is a pumping station, which lifts into this sewer the drainage brought down by the sewers on the river Effra.

There is also a branch conduit from the districts of Bermondsey and Rotherhithe, which delivers to the Deptford pumping station, the contents being then pumped into the Southern Outfall Sewer.

From Deptford the united sewage flows down to Crossness by the Southern Outfall Sewer.

At Crossness the whole is pumped by steam power to the height necessary to allow it to flow into the river.

The following data, given in evidence before the Royal Commission by Sir Joseph Bazalgette, will give a general idea of the magnitude of the works :—

PUMPING STATIONS.

	Total Nominal Horse Power.	Lift.
For Northern Sewage.		Feet.
Pimlico	480	18
Abbey Mills	1,140	36
For Southern Sewage.		
Deptford	500	18
Crossness	1,000	10 to 30
For Storm Relief Overflows. (South Side only.)		
Effra	200	5 to 18
Falcon Brook	200	3 to 10½

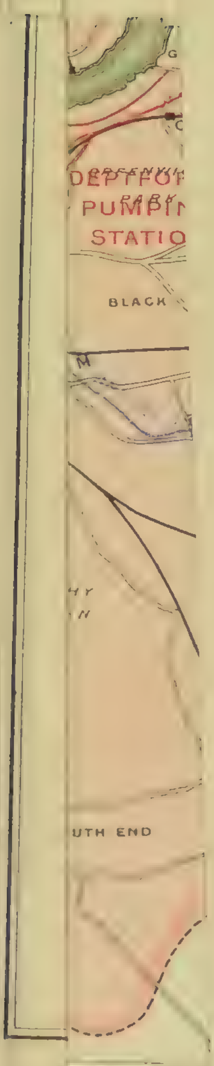
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TABLE XXVII.

North Side of Thames.	Areas from which Sewage is intercepted. Inside Metropolis.	Outside Metropolis.	Total.	Length of Main Intercepting Sewers, including Branches.	Dimensions, Largest and Smallest.	Inclinations, Greatest and Least.
	Square Miles.	Square Miles.	Square Miles.	Miles.		Feet per mile.
High Level	8·29	—	8·29	7½	9′ 6″ × 12′ 0″ . 4′ 0″ Barrel . .	75 to 4.
Mid Level	16·47	Kilburn . . 1·34 S. Hornsey 0·37 1·71	18·18	12¾	10′ 6″ Bl. . . 4′ 0″ × 2′ 8″ .	17½ to 2.
Low Level, including Western Division .	23·74	—	23·74	21	10′ 3″ Bl. . . 3′ 9″ × 2′ 6″ .	10·37 to 2.
Outfall Sewer	—	—	—	5½	3 Culverts, 9′ 0″ × 9′ 0″ 2 Culverts, 9′ 0″ × 9′ 0″	2.
	48·50A		50·21C	46¾		
Area of Metropolis [North] *not* drained into intercepting sewers.						
	1·47B					
	49·97					

A. Of this area 3·40 square miles is common or park land, and 0·87 square miles is water.

B. This area consists of parts of Hackney marshes, North Woolwich, and a detached part of the metropolis near Muswell Hill.

C. In addition to the above, the district of the Hornsey Local Board contributes sewage from a present population of about 22,000, the quantity being restricted ultimately to 500 cubic feet per minute. A part of the Stamford Brook drainage area contributes also the sewage from a small population, but its number cannot be ascertained. The same area also contributes surface water to the metropolitan system, but the Metropolitan Board have determined to intercept this from their sewers and discharge it into the river at the extreme western boundary of the Metropolis. This is one of the works included in the 1,500,000*l*. to be expended to prevent floodings from rain.

TABLE XXVIII.

Areas from which Sewage is intercepted.				Length of Main Intercepting Sewers, including Branches.	Dimensions, Largest and Smallest.	Inclinations, Greatest and Least.
South Side of Thames.	Inside Metropolis.	Outside Metropolis.	Total.			
	Square Miles.	Square Miles.	Square Miles.	Miles.		Feet per mile.
High Level	24·71	Upper Norwood, 0·54	25·25	$14\frac{5}{8}$	Two 10′ 6″ × 10′ 6″ . . . . One 3′ 0″ × 2′ 0″	52·8 to $2\frac{1}{2}$.
Low Level	20·72	—	20·72	$14\frac{1}{8}$	Two 7′ 0″ × 7′ 10″ One 4′ 0″ Bl. . .	$4\frac{1}{2}$ to 2.
Outfall Sewer	5·78	—	5·78	$7\frac{1}{2}$	11′ 6″	2.
	51·21D		51·75F	$36\frac{1}{4}$		
Areas of Metropolis [South] *not* drained into intersecting sewers.	16·57E					
	67·78					

D. This contains 3 square miles of common land and park, and 0·56 square miles of water.

E. This contains $\frac{1}{2}$ square mile of common land and parks, $3\frac{1}{2}$ square miles of marsh lands, 2·15 square miles draining away from the Metropolis, and the rest in land of a rural or agricultural character, situate in the localities of Rochampton, Eltham, and Mottingham, which will never probably be more than sparsely built over.

F. In addition to this, 0·92 square mile of Beckenham contributes sewage only to the intercepting system.

(153) *Arrangements at the Main Outfalls.*

The outfall sewers do not discharge directly into the Thames; they terminate in large covered reservoirs, from which the sewage is intended to be discharged only at certain times of the tide. The discharge commences at high water, and it was intended, according to the report of Messrs. Bidder, Hawksley, and Bazalgette, to have been completed "during the first two and a half hours of the ebb tide." As a matter of fact, however, it usually continues for three or four hours, after which time it is intended that the penstocks are to be closed, allowing the sewage to collect in the reservoirs for discharge on the next tide.

The reservoir at Barking Creek covers about 9½ acres, and holds 35,000,000 gallons, or 5,600,000 cubic feet. That at Crossness covers about 6½ acres, and contains 25,000,000 gallons, or 4,000,000 cubic feet. (In the report of Messrs. Bidder, Hawksley, and Bazalgette, it was recommended that the area of the Barking Reservoir should be about 12 acres, and of that at Crossness about 7 acres.)

The bottoms of the reservoirs are 2·75 feet above ordnance datum, or 1·19 feet above half tide level. At the top they are provided with overflow weirs, from which, when the reservoirs are full, the sewage passes into the river.

At Barking the overflow weirs are at the height of 16·25 feet above ordnance datum, so that the available depth is 13·5 feet. At Crossness the weirs are 2·5 feet higher, giving an available depth of 16 feet.

The works are so constructed that at Crossness the discharge is always below water; but at Barking this is not the case, the discharge partly taking place over the foreshore. The latter arrangement is a departure from the condition laid down in Messrs. Bidder, Hawksley, and Bazalgette's report, that "in both cases the sewage should be discharged into the river through submerged pipes, terminating below low-water mark."

The sewers are capable of bringing down much more than the reservoirs will hold, and when they do so, there will be an overflow into the river from the reservoirs at any time of the tide, as at the storm outlets.

At the beginning of 1881 there were overflows on 43 days from Crossness, and more days at Barking.

It was intended that the reservoirs were to be added to from time to time, and there is no doubt that more storage room is necessary.

The general direction of the main intercepting sewers is from east to west, more or less parallel with the river, the other main sewers flowing to the river. These sewers are all scheduled in the Metropolis Local Management Act 1855, and are invested in the Metropolitan Board of Works, which now of course gives place to the London County Council. The schedule describes their general course and outlet in that year (1855); for example take the King's Scholars Pond Sewer,[1] the schedule describes it as commencing "in the Finchley Road, at about 1500 feet above Junction Road toll gate, and discharges into the River Thames at the Equitable Gas Works, about 700 feet above Vauxhall bridge." This is not accurate now for it discharges into the Main Low Level Sewer,but has a storm overflow into the Thames. The other sewers not mentioned in the Metropolis Local Management Act are under the control of the various local boards, or vestries, and are vested in and maintained by them.

Quantity of Sewage.—The daily quantity of sewage discharge from Crossness and Barking is enormous. The flow of sewage proper is estimated at an average of 16,000 cubic feet per minute, which is 23,000,000 cubic feet per diem.[2] The river at low water in the neighbourhood of the outfalls is about 2,000 feet broad, and has a sectional area of about 30,000 square feet, so that there is discharged into it every day as much undiluted sewage as would fill a length of 650 feet of this part of the river at low water.

If the quantity of foul matter which this discharge must of

[1] The old state of things was as follows:—"Nearly the whole of the drainage of the large and populous parishes of St. Marylebone, of St. George, Hanover Square, of a portion of St. John, Hampstead, and of the greater part of St. James, Westminster, is conveyed away by the King's Scholars Pond main sewer, which has its source at Hampstead, and running through these parishes and this low flat of land discharges itself into the Thames near Vauxhall Bridge. While the river water is above its outlet, that is, during the space of five hours and six minutes in every twelve hours, the drainage is locked in. This sewer therefore may be considered the grand cesspool of the before-named parishes." (Mr. John Phillips's evidence Met. San. Commission, 1847.)

[2] Crossness outfall delivers, according to a six years' average, 74·6 millions of gallons a day; Barking, 85·2. The proportion that Crossness bears to Barking is therefore as 1 : 1·14.

necessity contain, is estimated the quantities are astounding. The quantity of fæces alone, in their natural state, passing from 3,800,000, people has been stated at something like 400 tons a day; but adding to this the urine, and the foul matter from other sources and of other kinds, the total quantity must be very much larger.

The volumes which the outfall sewers are calculated to carry are—

	Cubic feet per second.	Millions of Gallons per day.
For the North	545	294
,, South	233	126
	778	420

Storm Overflows.—It is a consequence of the system adopted that there are certain times in the year when the rainfall is so great that the total quantity flowing off must exceed the discharging capacity of the intercepting conduits; and at these times there is no alternative but to allow the superfluous quantity to be discharged directly into the river, independently of the interception, and at the old points of discharge within the metropolitan area.

Suitable arrangements are made for this purpose. The sizes of the intercepting sewers being graduated to take the calculated quantity, at the points of interception of each of the original sewers there is formed a long weir; and when the rain exceeds the calculated quantity, the surplus contents of the sewer flow over this weir and follow the former course down the original sewer, from the mouth of which the fluid escapes directly into the river.

There are 48 of these storm or relief outlets within the metropolitan area, 35 on the north side and 13 on the south. A list of them, showing their positions and dimensions, is given by Sir Joseph Bazalgette in Q. 12,728 of his evidence before the Royal Commission; they are generally of large size, capable of delivering large discharges when they come into action; they have been added to recently.

For the prompt relief of certain low-lying districts the storm discharge is aided by steam power. On the banks of the Effra at Nine Elms there is a pumping station of 200 horse-power for lifting the storm waters into the river, when they are penned up by the tide. There is another at the Falcon Brook of the same power.

The fluid discharged from these storm outlets does not consist merely of rain water, but must contain a mixture of sewage.

Cost.—The total cost of the Main Drainage works up to 1883 has been stated in the Reports of the Metropolitan Board to be about 4,600,000*l.*

The portion of the Metropolitan drainage, that is admirably conceived and executed is the great intercepting sewer system, while the points which are most open to criticism, and indeed cannot be well defended, are the number of storm overflows which in times of heavy rain, pollute the river within the metropolis, and the great and cardinal defect, that the sewage goes into the river without being first passed through land; this is indeed the final recommendation of the Royal Commission their recommendations being as follows:—

"1. Our opinion of the evils described in our first report, as resulting from the present system under which sewage is discharged into the Thames by the Metropolitan Board of Works, is much strengthened, and we believe these evils demand a prompt remedy.

"2. We are of opinion that it is neither necessary nor justifiable to discharge the sewage of the metropolis in its crude state into any part of the Thames.

"3. We are of opinion that some process of deposition or precipitation should be used to separate the solid from the liquid portions of the sewage.

"4. Such process may be conveniently and speedily applied at the two present main outfalls.

"5. The solid matter deposited as sludge can be applied to the raising of low-lying lands, or burnt, or dug into land, or carried away to sea.

"6. The entire processes of precipitation and dealing with the sludge can be, and must be, effected without substantial nuisance to the neighbourhoods where they are carried on.

"7. The liquid portion of the sewage, remaining after the precipitation of the solids, may, *as a preliminary and temporary measure,* be suffered to escape into the river.

"8. Its discharge should be rigorously limited to the period between high water and half ebb of each tide, and the top of the discharging orifice should be not less than six feet below low water of the lowest equinoctial spring tides.

"9. By these means much of the existing evil will be abated.

"10. But we believe that the liquid, so separated, would not be sufficiently free from noxious matters to allow of its being discharged at the present outfalls as a *permanent* measure. It would require further purification; and this, according to the present state of knowledge, can only be done effectually by its application to land.

"11. In the case of the metropolis, the best method of applying

the liquid to land, with a view to its purification, would be by intermittent filtration. We have reason to believe that sufficient land, of a quality suitable for this purpose, exists within a convenient distance of the northern outfall. The liquid portion of the sewage would be pumped up to this land from the separating works, and after filtration would be conducted to the river.

"12. We do not know whether suitable land, in sufficient quantity, can be found in convenient positions near the southern outfall. If not, the liquid must be conveyed across to the north side by a conduit under the river.

"13. If suitable land, in sufficient quantity and at reasonable cost, cannot be procured near the present outfalls, we recommend that the sewer liquid, after separation from the solids, be carried down to a lower point of the river, at least as low as Hole Haven, where it may be discharged. In this case, it will also be advisable that the liquid from the southern sewage should be taken across the river, and the whole conveyed down the northern side. It may be found that the separating process can be effected more conveniently at the new than at the present outfalls; this will depend on various considerations of cost and otherwise.

"14. If the outfalls are removed further down the river, the main conduit or conduits may, if thought desirable, be made of sufficient capacity to include a general extension of the drainage to the whole of the districts round London, as recommended by Sir Joseph Bazalgette and Mr. Baldwin Latham. In new drainage works, the sewage should be, as far as possible, separated from the rainfall."

CHAPTER XVIII.

CALCULATIONS OF THE DISCHARGE OF SEWAGE OR WATER OR OTHER LIQUIDS.

(154) *Eytelwein's Formulæ.*

THE formulæ for calculating the velocity of discharge, the quantity of cubic feet per minute, and other data, are most accurately obtained by the use of Eytelwein's formulæ, the formulæ having been tested by experiment and found to agree closely.

Let $d =$ the diameter of the pipe in inches, Q the quantity of water in cubic feet per minute, l the length of the pipe in feet, and $h =$ the difference of level between the surface of the water in the reservoir and at the end of the pipe, or the head; any three of the quantities being known, the fourth may be calculated by the following formulæ.

$$(1)\ d = \sqrt[5]{\frac{\cdot 0448\ Q^2\ (l + 4{\cdot}2d)}{h}}$$

$$(2)\ Q = \sqrt{\frac{hd^5}{\cdot 0448\ (l + 4{\cdot}2d)}}$$

$$(3)\ l = \frac{hd^5}{\cdot 0448\ Q^2}\ 4{\cdot}2d$$

$$(4)\ h = \frac{\cdot 0448\ Q^2\ (l + 4{\cdot}2d)}{d^5}$$

These formulæ are much easier worked by logarithms. Expressed logarithmically they become :—

(1) $\log d = \frac{1}{5}\,[2 \log\ Q + \bar{2}{\cdot}6515 + \log\ (1 + 4{\cdot}2d) - \log h]$.

(2) $\log Q = \frac{1}{2}\ \{1{\cdot}3485 + \log h + 5 \log d - \log\ (l + 4{\cdot}2d)\}$

(3) $\log\ l = 1{\cdot}3485 + \log\ h + 5\ \log\ d - 2\ \log\ Q$ [neglecting $- 4{\cdot}2d$.]

(4) $\log h = 2 \log Q + 2{\cdot}6515 + \log\ (l + 4{\cdot}2d) - 5 \log d$.

The following are examples of the application of formulæ 2 and 4, taken from Mr. Henry Law's useful treatise on logarithms :—

"What quantity of water will be discharged by a pipe 18 inches in diameter, 5,371 feet long, and under a head of 75 feet?
Ans. 761·9 cubic feet per minute.

"What head will be required to force 350 cubic feet per minute through a pipe 15·5 inches in diameter, and 3,640 feet long
Ans. 22·739 feet."

The above formulæ give the rate of discharge in pipes under pressure; but in the case of drains and sewers it is most frequently required to ascertain both the velocity and rate of discharge when only partially filled. Putting D for the diameter in feet of a circular sewer, L for the length in feet in which the sewer falls one foot, v the velocity in feet per minute, Q the quantity discharged in cubic feet per minute, and c and s co-efficients the values of which for every tenth of the diameter are given in the table below, then

$$v = c\sqrt{\frac{D}{L}}$$

$$\text{and,} \quad Q = s\sqrt{\frac{D^5}{L}}$$

Table XXIX.

Height filled. $D=1$	Value of c.	Logarithm of c.	Value of s.	Logarithm of s.
0·1	1424	3·153650	58	1·765107
0·2	1963	3·292853	219	2·341388
0·3	2337	3·368617	463	2·665651
0·4	2616	3·417631	767	2·885047
0·5	2826	3·451165	1110	3·045224
0·6	2978	3·473939	1465	3·165928
0·7	3076	3·488012	1806	3·256821
0·8	3117	3·493769	2100	3·322154
0·9	3086	3·489329	2297	3·361207
1·0	2826	3·451165	2220	3·346254

In the case of an oval sewer, of the usual form in which the radii of the crown, sides, and invert are respectively equal to $\frac{1}{3}$,

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These formulæ are much easier worked by logarithms. Expressed logarithmetically they become:—

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(2) $\log Q = \frac{1}{2}\,\{1\cdot 3485 + \log h + 5 \log d - \log (l + 4\cdot 2d)\}$

(3) $\log l = 1\cdot 3485 + \log h + 5 \log d - 2 \log Q$ [neglecting $-4\cdot 2d$.]

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$$v = c\sqrt{\frac{D}{L}}$$

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0·6	2978	3·473939	1465	3·165928
0·7	3076	3·488012	1806	3·256821
0·8	3117	3·493769	2100	3·322154
0·9	3086	3·489329	2297	3·361207
1·0	2826	3·451165	2220	3·346254

In the case of an oval sewer, of the usual form in which the radii of the crown, sides, and invert are respectively equal to $\frac{1}{3}$,

1 and $\frac{1}{6}$, the height of the sewer being 1, putting H for the height of the sewer in feet, and c and k co-efficients the values of which for every tenth of the height are given in the table below, the values of the other letters being the same as before, then

$$v = c\sqrt{\frac{H}{L}}$$

$$\text{and,} \quad Q = k\sqrt{\frac{H^5}{L}}$$

TABLE XXX.

Height filled. $H=1$.	Value of c.	Logarithm of c.	Value of k.	Logarithm of k.
0·1	1344	3·128419	30	1·473257
0·2	1750	3·242924	105	2·020306
0·3	2023	3·305938	219	2·340413
0·4	2231	3·348462	367	2·564759
0·5	2394	3·379206	542	2·734014
0·6	2524	3·402000	736	2·866758
0·7	2623	3·418773	939	2·972790
0·8	2686	3·429076	1134	3·054783
0·9	2687	3·429285	1283	3·108371
1·0	2484	3·395102	1268	3·103062

In the case of a circular sewer the velocity is greatest when filled to 81 hundredths of the diameter, and the quantity discharged is greatest when filled to 95 hundredths of the same; and in that of an oval sewer the greatest velocity is when filled to 85 hundredths of the height, and the greatest discharge when filled to 96 hundredths of the same.

As an example, what will be the velocity and rate of discharge in a circular sewer 2 feet in diameter, having a fall of 1 in 500, when filled to a height of four-tenths of its diameter?

$$\begin{aligned} \text{Then log. } D &= 0{\cdot}301030 \\ \text{log. } L &= \underline{2{\cdot}698970} \\ &\quad 2)\bar{3}{\cdot}602060 \\ &\quad \overline{\bar{2}{\cdot}801030} \\ &\quad \underline{3{\cdot}417631} \\ &\quad 2{\cdot}218661 = \text{log. of } 165. \end{aligned}$$

$$
\begin{array}{rl}
\text{And log. } D^5 = & 1{\cdot}505150 \\
\text{log. } L = & 2{\cdot}698970 \\
\hline
2) & \bar{2}{\cdot}806180 \\
\hline
 & \bar{1}{\cdot}403090 \\
 & 2{\cdot}885047 \\
\hline
 & 2{\cdot}288137 = \text{log. of } 194.
\end{array}
$$

Therefore the velocity will equal 165 feet per minute, and the quantity discharged 194 cubic feet in the same time.

(155) *Head of Water.*

The terms "head" of water, "total head," "loss of head," are technical, and apply to height of water. Thus with a pipe 20 feet high connected with a reservoir which has 6 feet of water in it; if the pipe be filled, at the orifice of the tap, there would be a pressure of water, equal to the height of the water above the orifice of the tap and this would be a head equal to 26 feet. It could however be proved, that the theoretical velocity due to a column 26 feet high, at this point would not be quite attained, because of the more or less rough state of the interior of the pipe; this is expressed by loss of head due to friction. The pressure of water in the pipe just considered is called "hydrostatic pressure," to distinguish it from "hydraulic pressure," which is the pressure in flowing water, the other being the pressure in still water. There is an important distinction between the two, for in the latter the pressure is generally a changing pressure; for instance, in the case of the cistern being emptied, as the level of the water lowered there would be a continual "loss of head."

Supposing that there is, no friction, the loss of head in producing a given increase of velocity is equal to the height of vertical fall which would produce the same increase of velocity in a body falling freely; this may be expressed as the loss of head equals the height due to the acceleration; if the particle start from a state of rest, that height is called the height due to the velocity, and is given by the following formula, where v equals the velocity in feet per second, and h = the height in feet.

Then $v = 8{\cdot}025 \sqrt{h}$; and if $h = 20$, then $v = 8{\cdot}025 \times 4{\cdot}47 = 35{\cdot}87$.

If friction is taken into account a co-efficient F is got out by

experiment expressing the proportion which the loss of head by friction bears to the height due to the velocity, and the formula becomes

$$v = 8{\cdot}025 \sqrt{\frac{h}{1+F}}$$

Supposing it be required to find the velocity for the flow of liquid at two different inclinations, the velocity in the one case being given, it is easy to find the other, for the velocity will vary inversely as the square roots of the fall.

For example, if the velocity in a sewer is 65 ft. per second with a fall of 25 ft. in 100, and it is desired to know what would the velocity be if the same sewer had a fall of 4 ft. in 100, it may be stated as follows: as $\sqrt{4} : 65 :: \sqrt{25} = 26$ ft. per second, for the square root of 4 is 2 and the square root of 25 is 5, and $\frac{2}{5}$ of $65 = 26$ ft. per second, or putting it the converse way, supposing a fall of 4 ft. per 100 gives a velocity of 26, what will a fall of 25 in the same length produce? then $\frac{5}{2} \times 26 = 65$ ft. per second.

If a fall of 1 in 100 gives a velocity of 13 ft. per second, what will be the velocity if the same pipe is placed perpendicularly?

In this latter case the fall is of course 100, then $\frac{\sqrt{100}}{\sqrt{1}} \times 13 = 130$ ft. per second.

If again the question is put as follows: A sewer laid with a fall of 9 ft. in 100 gives a velocity of 39 ft. per second, what will be the velocity in a sewer of the same size laid with a fall of 1 ft. per mile?

1 mile = 5,280 ft., hence $\frac{100}{5280} = {\cdot}01895$; and the fall is therefore ·01895 in 100, $\frac{\sqrt{{\cdot}01895}}{\sqrt{9}} \times 39 = {\cdot}1768$ ft. per second.

(156) *Kutter's Formula.*

This is a formula which has recently been simplified by Mr. R. Hering.[1] The original formula reads:—

[1] Engineers' Club, Philadelphia, June, 1888; Sanitary News, December, 1888.

(1)
$$v = \frac{41{\cdot}6 + \dfrac{1{\cdot}811}{n} + \dfrac{0{\cdot}00281}{s}}{1 + \left(41{\cdot}6 + \dfrac{0{\cdot}00281}{s}\right)\dfrac{n}{\sqrt{r}}} \sqrt{rs}.$$

in which:

v = velocity in feet per second.
n = coefficient of roughness of wetted perimeter.
r = hydraulic radius.
s = slope of water surface.

The term $\dfrac{0{\cdot}00281}{s}$, which occurs twice, can be readily eliminated by substituting for the value s the least grade that we are likely to have in sewers—namely, 1 : 2500. Then we obtain the constant value: $\dfrac{0{\cdot}00281}{0{\cdot}0004} = 7{\cdot}0$, which reduces the formula to:

(2)
$$v = \frac{48{\cdot}6 + \dfrac{1{\cdot}811}{n}}{1 + 48{\cdot}6\,\dfrac{n}{\sqrt{r}}} \sqrt{rs}.$$

This substitution influences the result but little. It tends to make the smaller sewers slightly larger than the original formula. There would be in fact no difference at all for a sewer about 13 ft. in diameter, whatever its grade, and the difference would increase, as the size diminishes and the grade increases, up to an excess of about 5 per cent. for a sewer of 1 ft. diameter, at a grade of 4 ft. for 100. This excess of about 5 per cent. is practically the maximum error for sewer application, and it is always on the safe side.

But the formula can still further be simplified by substituting a numerical value for n.

According to Kutter, for glazed pipe we would have to put $n = {\cdot}010$. But owing to the frequency of joints and the imperfect shape due to the process of burning, which causes projection in the sewer at nearly every joint, it is not safe to assume so low a coefficient. Besides, the flow of sewage is slower than that of clear water, because the suspended matter drags at the perimeter and tends to hold the water back. Allowing for these causes we generally get nearer the truth if for pipe-sewers we put $n = {\cdot}013$.

For brick sewers, on the other hand, Kutter gives $n = \cdot 013$.

It has been found, however, that if well built n can often be reduced to ·012. Still, for sewage flow, the resistance is again greater, and Hering finds that by adopting the value of $n = \cdot 013$ also for brick sewers we are about as nearly correct as it is necessary to be in the majority of cases, and err slightly on the safe side, if we err at all.

By substituting this value in formula 2 we get:

(3)
$$v = \frac{188\sqrt{rs}}{1 + \frac{0 \cdot 63}{\sqrt{r}}}$$

or,

(4)
$$v = \frac{188\, r\sqrt{s}}{0 \cdot 64 + \sqrt{r}},$$

which is, therefore, not only a sufficiently accurate, but also a sufficiently simple, formula for general use in sewer work.

Stated in general terms, the formula reads:

(5)
$$v = \frac{A\, r\sqrt{s}}{B + \sqrt{r}}.$$

By substituting the following values for the coefficients A and B, it can be used for any other degree of roughness than $n = \cdot 013$ as may be thought proper.

TABLE XXXI.

DIFFERENT DEGREES OF ROUGHNESS.	A.	B.
For $= n$ 0·011, very smooth, with even joints . .	213	0·54
For $= n$ 0·012, very smooth, with even joints . .	200	0·59
For $= n$ 0·013, average, with even joints	188	0·64
For $= n$ 0·014, average, with even joints	178	0·69
For $= n$ 0·015, poorly built brick work, with washed out joints	169	0·73

For *very* smooth and regularly-shaped sewers we might say; $v = \frac{200\, r\sqrt{s}}{0 \cdot 6 + \sqrt{r}}$, which formula is easily remembered and easily solved.

CHAPTER XIX.

DISPOSAL OF SEWAGE.

(157) *Irrigation of Land.*

THERE are two kinds of irrigation, "broad irrigation" and "intermittent filtration." These are thus distinguished by the Royal Commissioners on Sewage Discharge: "Broad irrigation means the distribution of sewage over a large surface of ordinary agricultural ground, having in view a maximum growth of vegetation (consistently with due purification) for the amount of sewage supplied. Filtration means the concentration of the sewage, at short intervals on an area of specially chosen porous ground, as small as will absorb and cleanse it; not excluding vegetation, but making the produce of it of secondary importance. The intermittency of application is a *sine quâ non* even in suitably constituted soils, wherever complete success is aimed at."

In broad irrigation, the sewage is simply delivered in special channels on to the land, which should be well drained, and vegetables and crops grown thereon; it is a plan well adapted to certain villages and small towns, where local circumstances are favourable.

The best soil is that of a sandy loam, its successful application requires about 1 acre to every 120 of the population. Broad irrigation has been lately carried out on a large scale at Berlin. English examples are Croydon, Cheltenham, and Blackburn.

Intermittent downward filtration, has been for some years the favourite method of dealing with sewage, the sewage going on to the filter beds in the crude state, or after first previous precipitation, the beds receive the effluent; a very perfect method of purification is secured by this last process.

The principle of making filter beds for intermittent filtration

may be exemplified by a brief description of those at Merthyr-Tydvil (population 14,500), 20 acres of land are used for the filtering areas.

The sewage is first treated with lime, and is strained in special tanks through cinders; it then flows on to the conduit which conveys it to the filtering areas, these last being arranged on a plan devised by Mr. Bailey Denton. The land is a loamy soil, 18 in. thick overlaying a bed of gravel. The whole area is underdrained to a depth of from 5 to 7 ft. Lateral drains placed at regular distances the one from the other run towards the main or effluent drain, which drain is everywhere 6 ft. deep. The surface of the land has been formed into beds; these slope towards the main drain with a fall of 1 : 150. The surface is ploughed into ridges; on these, vegetables are planted or seeds sown; the line of the ridged furrow is in the direction of the under drain. Along the raised margin of each bed in each area delivering carriers are placed, one edge being slightly depressed. The strained sewage passes from the conduits into the delivering carriers, and as it overflows the depressed edges, runs gently into and along the furrows down to the lowest and most distant part of the plot. The sewage continues to be so delivered for six hours; then an interval of rest for eighteen hours takes place and again the land is thoroughly charged with the fertilising stream. The water percolates through the 6 ft. of earth, and reaches the lateral drains, which convey it to the main effluent drain. In addition to this land, used as filtering areas, there are a number of acres laid out for irrigation.

Intermittent irrigation is now carried on largely both at home and abroad, with the most satisfactory results as regards purity of effluent, but with varying results as to the money value of the resulting crops, in some cases a considerable return being received, in others the returns have not been satisfactory; this is what might be expected, the conditions of the soil and other things varying.

One of the most unsuitable lands for intermittent irrigation is a stiff clay soil, but even here it is stated that a good filter bed can be constructed at a cost of about £600 to £800 per acre by burning the clay into ballast and laying down the ballast to a depth of about 3 ft. with layers of alluvial or other rich soil interposed.

(158) *Chemical Processes for the Treatment of Sewage.*

The number of processes for the clarification of sewage which have been proposed and patented are very numerous, as may be seen from the following list of patents:

TABLE XXXII.

Names of Substances.	Inventor.	Date.
Sulphate of iron	Deboissieu	1762
Chlorine	Hallé	1785
Lime	Estienne	1802
Powdered charcoal	Giraud	1805
Chlorine and chloride of lime	Guyton Morveau	1805
Ashes	Chaumette	1815
Sand	Duprat	1818
Sulphate of iron	Briant	1824
Chloride of sodium	Labarraque	1824
Waste chloride of manganese	Payen and Chevalier	1825
Sulphate of lime	Siret	1827
Animal charcoal	Frigerio	1829
Peat	Guibourt and Sanson	1833
Charcoal and calcined marl or river mud	Pottevin	1836
Sulphates of iron and zinc with tan and tar	Siret	1837
Earth, lime and waste substances	Rossier	1837
Peat ashes	D'Arcet	1840
Metallic oxides and carbon	Krafft and Suequet	1840
Chloride of zinc	Sir Wm. Burnett	1840
Schist coke	Hompesch	1841
Trade refuse, charcoal, and ashes	Albert	1842
Powdered lignite	Jourdan	1843
Impure alum	Siret	1843
Sulphate of zinc, charcoal, and clay	Gagnage and Regnault	1844
Persulphate of iron	Baronnet	1845
Schist coke	Du Boisson	1845
Chlorides of iron and zinc	Dubois	1846
Lime and precipitating tanks	Higgs	1846
Nitrate of lead	Ledoyten	1847
Waste salts of iron, lead zinc, &c., with pyroligneous matters, ashes, &c.	Brown	1847
Pyrolignate and perchloride of iron	Ellerman	1847
Impure chloride of manganese	Young	1847
Dried sea-weed, lime, and sulphate of lime and zinc	Salman	1848
Peat charcoal	Rogers	1848
Charcoal, soot, mineral salts &c.	Legras	1849
Spent tan, carbonised	Tarling	1850
Fresh bark, sulphate of iron, and peat charcoal	Angely	1850
Metallic sub-salts, as of iron, alumina, &c.	Browne	1850
Milk of lime and collecting the deposit	Wicksteed	1851
Acids and metallic salts, and filtrations through charcoal, clay, peat, gypsum, &c.	Dover	1851

TABLE XXXII. (*continued*).

Names of Substances.	Inventor.	Date.
Lime, sulphates of alumina, and zinc, and charcoal	Stothert	1852
Lime, magnesian earth, sulphate of zinc or iron, and vegetable charcoal	Gilbee	1852
Sifted ashes, breese, or peat charcoal	Perks	1852
Sulphate of zinc, potash, alum and sand with waste tan, ashes, lime, soot, &c.	Pinel	1853
Metallic sulphates, metallic chlorides, or charcoal and magnesian salts	Herapath	1853
Salts produced in working galvanic batteries	Dering	1853
Peat or bog earth containing salts or oxides of iron	Dimsdale	1853
Peat and other charcoal and chloride of sodium, &c.	Macpherson	1853
Animal charcoal, alum, carbonate of soda and gypsum	Manning	1853
Magnesia and lime with sulphurous and carbolic acids	Smith and McDougall	1854
Lime and finely-divided charcoal	Wicksteed	1854
Boghead coke	Herapath	1854
Soft sludge from alum works with lime and charcoal	Manning	1854
Peat charcoal carbonised with oil of vitriol	Longmaid	1855
Alum schist or shale, and other aluminous mineral, with lime and charcoal	Manning	1855
Manganates and permanganates	Condy	1857
Superphosphate of lime with magnesia and lime	Blyth	1858

The chief processes which have survived, and are in actual use are those in which lime, salts of iron, and salts of alumina are used either singly or in combination, examples therefore will be considered under these respective headings; but, it will first be useful to state the nature of the liquid to be treated, and next the chemical action by which a precipitate is formed and the method of its action.

(159) *Composition of Sewage.*

Sewage is a very complex liquid, varying according to the season, water supply and manufactories in reaction and content of solid matter. It is usually alkaline, save the sewage of towns like Birmingham, in which vast volumes of "pickling" or strongly acid liquors are cast into the sewers. It contains soluble and insoluble compounds of fatty acids with bases, ammonia, sulphide of ammonia, finely divided cellulose derived from paper, fatty matters.

and many other soluble and insoluble substances. According to the Rivers Pollution Commission, the average composition of water closet towns sewage, in 100,000 parts is 44·69 parts of suspended matters, of which 24·18 are mineral, the rest organic, 72·2 parts of solid matters are in solution; that is to say, a sample of carefully filtered sewage on evaporation would leave solid matter in that proportion. A gallon therefore contains 50·5 grains of dissolved matter, a quantity which might about fill a teaspoon; the total nitrogen in the 100,000 parts is about 7·7 but the extremes vary widely. The dry weather sewage of the metropolis is estimated as containing 60 tons of sewage per annum per head (224 gallons weigh a ton); the lowest money value which can be assigned to this is over £1,000,000.

(160) *General Reactions on the addition of Lime, Iron, or Alumina.*

If to this complex liquid either hydrated lime or a solution of lime be added a precipitate is formed, the lime combines with the free carbonic acid or it decomposes carbonates of the alkalis, and slowly sinks to the bottom as lime carbonate; in sinking it carries down a considerable portion of organic matter and thus clears the liquid.

If a salt of iron is added, such as sulphate of iron, the reaction is more complex, the sulphuric acid combines with the lime salts, and the result is that protoxide of iron is first formed. This acts as a carrier of oxygen, and the precipitate as before carries down in subsiding large quantities of organic matter some of which it may oxidise. If the iron salt is used alone the effluent is slightly acid. Subsequently any sulphide of ammonium present is decomposed and iron sulphide formed, and the sewage becomes from this reason more or less black. Sulphate of alumina when added to sewage is decomposed very similarly to sulphate of iron, hydrated alumina oxide being formed and slowly sinking to the bottom, lime or carbonate of lime in the presence of sulphate of alumina is converted into sulphate of lime.

(161) *Lime Process.*

Save when the sewage is acid, the proper amount of lime to add according to Dr. Stevenson should not exceed the hardness of the

water supply, that is to say, if the water supply possesses 12 degrees of hardness, then add 12 grains per gallon of lime. The lime is usually added in the form of milk of lime, that is to say slacked lime is mixed with water until a thin white sort of emulsion is formed. The Commission reported that the lime process was very simple and the least costly of any, but that it could not be profitable in an agricultural sense, and did not purify the sewage.

The lime process has been tried at Tottenham, at Blackburn and at Leicester.

(162) *Alumina Processes.*

The *phosphate process* of Messrs. David Forbes, F.R.S., and A. P. Price is an alumina process; phosphate of alumina is dissolved in hydrochloric or sulphuric acid and the solution added to the sewage.

Bird's process is the addition of a crude sulphate of alumina to sewage, the sulphate is formed by decomposing clay (that is alumina silicate) by sulphuric acid. The proportions used are 6 cwt. of pulverised clay and 120 lbs. of sulphuric acid to 200,000 gallons of sewage. It is in use at Stroud. The effluent is acid.

(163) *Salts of Iron.*

The "Sewage Purification Company" treat a powdered magnetic iron ore with sulphuric acid; the result is of course a solution of sulphate of iron, this is added in due proportion to the sewage; the effluent is acid.

(164) *Various Mixtures.*

In *General Scott's process* 10 cwt. of lime, and 5 cwt. of clay are added to 400,000 gallons of sewage, the sludge is burnt in a kiln, and ground into cement. General Scott's process was tried at Ealing.

Hille's process was tried at Wimbledon. It consists in adding to the sewage a mixture of 100 parts of lime, 6 of tar and 12 of calcined magnesium chloride.

Holden's process is the use of a precipitant consisting of a mixture of sulphate of iron, lime, and coal dust.

The A, B, C process consists in adding a mixture of ammonia, alum, clay, charcoal, Epsom salts (magnesic sulphate) and blood to sewage. According to the second report of the Rivers Pollution Commission

the practical application of the process was as follows: 1,027 gallons of river water held suspended or dissolved 3 cwt. of ammonia alum, 6 cwt. of moist clay, 15 lbs. of animal and 20 lbs. of vegetable charcoal, 20 lbs. of Epsom salts, and 4 lbs. of fresh blood in a magma of clay; this liquid the Commissioners found discharging into the sewage at the rate of about 210 gallons per hours at Leamington.

Dr. Anderson's process has been tried at Coventry. The sewage was mixed with a saturated solution of sulphate of alumina heated to the boiling point, the crude sulphate being made on the spot by means of sulphuric acid acting on clay or shale; after this treatment the sewage flowed on and was treated with milk of lime. According to the Commissioners the money results were not encouraging.

(165) *Sewage Sludge.*

From any of the above processes result a sludge and an effluent; the latter is sent into the nearest watercourse, the former requires special treatment. In some cases, as at Coventry, the sludge is reduced in bulk and made fairly dry by compression in Johnson's filter presses. These presses consist of a number of grooved discs arranged in series, each disc having a central perforation and being separated from the disc on each side by means of a filtering cloth. The liquid sludge is filtered through these cloths by air compressed at a pressure from 100 to 120 lbs. per square inch. The liquid escapes fairly rapidly, while the solid matters remain behind in a more or less solid cake: this is found the least expensive way of drying. In some cases the sludge is burnt, as at Acton, where the solid matters are mixed with house refuse and consumed without nuisance in a destructor.

(166) *Summary of Precipitation Processes.*

Dr. Corfield sums up the matter with regard to the processes of precipitation as follows: "All these precipitation processes to a certain extent purify the sewage and prevent the pollution of rivers, chiefly by removing the suspended matters from the sewage; but they all leave a very large amount of putrescible matter in the effluent water, and at least all the ammonia contained in the sewage (sometimes they add to it); the greater part of the phosphoric acid is

precipitated by some of them, while they increase the hardness of the river water, a matter of great importance if the stream be a small one.

"The manures that they produce are in every case very inferior, as may be expected from the known value of the sewage constituents which can be precipitated. They have all failed in producing valuable manure, because the valuable constituent of sewage *par excellence* is the ammonia, which of course invariably escapes in the effluent water and is lost to the manure; this shows the futility of all attempts to utilise sewage by precipitation alone."

Finally, there can be little doubt that the ultimate solution of the sewage problem is the utilisation of the sewage on land, either carrying it direct to the land, or in certain cases a combination of precipitation and irrigation by intermittent filtration.

SPECIAL SYSTEMS OF SEWERAGE.

(167) *The Shone System.*

In this system sewage is raised to the required height by means of compressed air. Its chief use is in towns which are unfavourably situated for disposal of the sewage by gravitation; it is in operation at Eastbourne, Wrexham, Southampton, Warrington, Henley and the Houses of Parliament, Westminster.

(168) *The Liernur System.*

This is in operation at Amsterdam and seems there to have given good results. Two separate sets of drains are required; the one is devoted exclusively to the evacuation of household waste water, rain water, and waste liquids from factories, these drains open into the canals. The second system of pipes receives the urine and sewage; the pipes are of small diameter (5 inch) and are connected with cylindrical iron reservoirs, in which a vacuum is maintained by means of powerful air vacuum pumps worked from a central station. The sewage is forcibly sucked into the reservoirs, hence the air from these small sewers never escapes *into* the house, any current set in motion being *from* the house to the reservoirs. The concentrated sewage thus obtained is dried and made into a *poudrette*, a valuable manure.

The Berlier system is in principle an exhaust pneumatic system very similar to the Liernur, it has been applied to a portion of Paris with great success.

(169) *The Treatment of Sewage by Electrolysis.*

This is the most recent method of treating sewage and is being carried on experimentally at Crossness. It is the invention of Mr. Webster, F.C.S. The sewage is electrolysed by flowing through long troughs, fitted at short intervals with large iron plates, the electricity being supplied by an Edison-Hopkinson-dynamo of 25 horse power giving an output of 1,600 amperes and 20 volts; the quantity that such a dynamo can deal with is a million gallons a day.

The chlorides in the water are split up at the positive pole, the nascent chlorine and oxygen unite forming hypochlorous acid, which partly attacks the organic matter, and partly attacks the iron plate forming hypochlorite of iron; at the negative plate, potash, soda, magnesia, ammonia, &c., are set free. The ferrous hypochlorite formed at the positive pole is acted upon by the free bases, that is by ammonia, sodium, potassium and magnesium hydrate and thus decomposed; a precipitate of ferrous hydrated oxide is produced. The bubbles of gas, buoy the hydrated oxide of iron up for some little time, so that the first effect is the reverse of precipitation, the under liquid becoming clear while the surface is thick with scum. As the fluid flows on to a precipitating tank, the gases diffuse into the atmosphere and then the oxide of iron falls to the bottom carrying with it most of the organic matters. The effluent is a fair one, the sludge can be pressed through a filter press or otherwise used.

(170) *Dry Systems of Sewage Disposal.*

Dry conservancy requires examination by modern bacteriological methods, it is by no means certain that a great number of pathogenic bacteria are by this system not preserved, instead of destroyed, whereas we know from actual experiment that in water carriage systems numerous harmful bacteria are absolutely destroyed by soaking in water; for example the bacillus anthracis, when not in the spore state is rapidly disintegrated if placed in

water. Putting these unsolved questions on one side and presuming that no harm results from the preservation of deodorised excreta in the vicinity of dwellings for a longer or shorter period according to facilities for scavenging, it has been found to be fairly successful for small communities, as for instance at Wimbledon camp and in various schools and institutions.

The type of the dry earth system is Moule's earth closet, which is merely a wooden box with a pail beneath, a reservoir of dry earth above and a simple apparatus for measuring and applying the requisite quantity of dry earth. In the cheaper kinds of closet, the earth is thrown on the excreta by hand; in the dearer kinds, there is an automatic arrangement. The quantity of dry earth necessary to use each time is about 1 lb.

The suitability of various soils is in the following order: (1) rich garden mould; (2) peaty soils; (3) black cotton soils; (4) clays; (5) stiff clayey loams; (6) red ferruginous loams; (7) sandy loams; (8) sands. It will almost be necessary to provide some other means of disposing of the slop water, which will also contain a considerable portion of the urine. One of the best methods of disposing of the slop water of a village provided with earth closets is by sub-irrigation. That is, to convey the slop water to a suitable area, into drains as follows: common agricultural drains are laid 12 in. deep upon a bed of larger pipes divided longitudinally in half; the slop water escapes at intervals between the joints of the agricultural pipes and is absorbed by the earth, and serves as a fertilizer for vegetation. In many cases an automatic flush tank connected with the sub-irrigation area is necessary. In isolated communities and villages favourably situated, the slop water runs into open channels, into fields, or is received in streams, and so long as the latter are not used for drinking purposes and no nuisance is created, it is not wise to meddle with these primitive arrangements.

(171) *The Pail System.*

This is after all but a variety of dry conservancy. It is in use in many of the large northern and midland towns, either wholly or partially, such as *e.g.* Rochdale, Nottingham, Birmingham, Leeds, Halifax, Edinburgh, Nottingham, Manchester and Salford.

In some places, notably in Glasgow, the excreta are placed in a movable receptable without any absorbent material and carted

away daily. The pail system in its best form involves some kind of absorbent material in the pail, for example in what is known as the "Goux System," called also "The Patent Absorbent Closet System" mixtures of any kind of vegetable and animal fibrous substances useless for other purposes are used as absorbents and these are mixed with a small proportion of iron or lime sulphate. These matters are pressed closely to the bottom and sides of the tub by means of a cylindrical mould which is afterwards withdrawn, leaving a cavity in the centre for the reception of the excreta. When these pails are emptied every two days, the results are good, but longer keeping usually exhausts the absorptive power.

A method of receiving urine into a mixture of salt and soot was exhibited in the Health Exhibition at Bolton in 1887, and received an award. This mixture certainly preserves to a remarkable degree urine and excrementitious matters generally, and the resulting mixture has a high manurial value. The trough latrines of Glasgow and Edinburgh Dr. Corfield considers as in effect the pail system adapted to large collections of people. This differs from the trough water-closets in not being connected with the sewers and requiring special scavenging arrangements for removal. A long fixed trough, slightly inclined towards one end, runs along under the seats of a row of closets; it is charged with only a small quantity of water and receives the total fluid and solid excrement of those using it. In the Glasgow factories there is one of these latrines to about every 180 to 200 hands; the contents are emptied daily down a vertical pipe into a large closed tank placed close to the ground, from this tank the contents are transferred to a closed cart and removed.

(172) *Water Closets.*

The position of a water closet should be where possible at the back of the house, and if in structural connection with the house a short passage or lobby interposed, possessing facilities for cross ventilation. All modern houses are built this way, but occasionally in old houses, the closet will be found in the centre of the building. In such a case the author has ventilated the closet fairly satisfactorily by carrying a Tobin's tube into the closet, and running up from the ceiling a 4 in. zinc pipe to the roof, a continuous up draught being created by a small jet of gas burning beneath the opening of the shaft.

There are three main types of water-closets, viz.: the pan water-closet, the valve closet, and the hopper closet. The pan closet is perhaps the most common form, and taking it all in all the most insanitary. The closet pan is closed, see Fig. 41 at the lower end by a sort of deep saucer which always contains a little water, and can be made to swing downwards by pulling the handle of a lever to which it is connected; the cavity in which it swings is called a container and is usually made of iron, from the container the closet contents pass into a ⊍ trap. The result of this arrangement is that the container gets soiled with offensive matter and cannot be

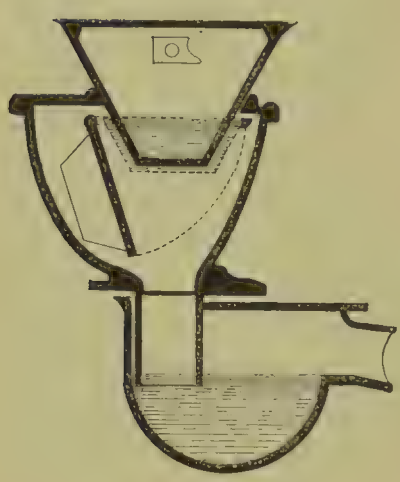

FIG. 41.

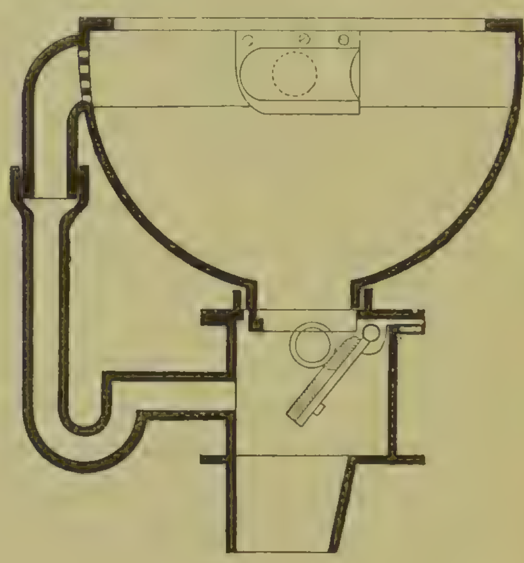

FIG. 42.

cleaned and is in effect a reservoir of foul air, the ⊍ trap is also one of the worst forms, and gets coated with excretal matters and often corroded by gases and liquids; it is likewise a smaller foul air reservoir. From these foul air reservoirs fœtid gas bubbles up and escapes whenever the closet is used. The original valve closet was the "Bramah." The lowest part of the basin is closed with a tight-fitting valve moving in a valve box, the box only being just large enough to allow of this movement, below the valve box is a syphon. To such closets there is an overflow pipe from the closet pan to prevent the accidental overflow of the flushing water over the edge of the basin (see Fig. 42). The overflow pipe as a rule passes into the valve box, and has a syphon bend. There is however some difficulty in keeping this overflow pipe properly trapped, and there have been

invented various contrivances for this purpose, *e.g.* in "Jenning's" valve closet the overflow is trapped by means of an india rubber ball, the ball allowing water to pass it in one direction, but any pressure of gas in the other only causes the ball to fit more closely to the end of the pipe. In Dent and Hillyer's valve closet, the overflow pipe is made larger than usual, so that the water seal is of greater bulk, besides which pressure in the valve box is rendered impossible, for a ventilating pipe is inserted into the valve box and continued into the open air. A better way to deal with the overflow pipe is to disconnect it from the valve box and carry it into the open air similarly to the warning pipe of a cistern, or to let it deliver it on the safe tray of the closet, and thus any waste will go down the waste pipe of the safe tray.

The hopper closet differs from either of the two previous closets in having no mechanical parts; it is simply a funnel terminating in a syphon, all that is required is a good flush of water and the contents pass away (Fig. 43). An improved form of the hopper closet

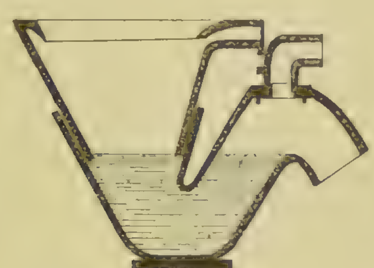

FIG. 43.

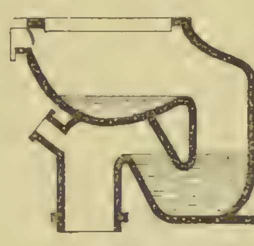

FIG. 44.

is what is known as the "wash-out closet;" this again has no mechanical parts, it is often made of glazed stoneware cast in a single piece, the closet is simply cleansed after use by a good flush of water (Fig. 44).

It is the custom to place a lead tray beneath closet pans on the floor, to prevent any overflow soaking through into the ceiling below. This is called a "safe;" there is a waste pipe from the safe, sometimes carried into the soil pipe, and sometimes into the D-trap it ought of course to be carried into the open air direct. The safe is usually boxed in together with the lower part of the closet by wood casing, and the whole space is not unfrequently a receptacle of dirt and filth and a cause of air contamination. The most modern closets have no safe, nor wood casing; the best form of all is without

doubt of the wash-out type, the basin and syphon of which are freely exposed to view, in which mechanical parts are absent, and in which deposits in the syphon or around the pan are rare.

The supply pipe to all the closets mentioned should be of sufficient size, $1\frac{1}{4}$ inch is the least admissible diameter for the supply pipe of a closet; the supply pipe should under no circumstances be directly connected with the drinking water cistern, nor what is still worse, with the service pipe of a constant supply system. Closets should have a separate cistern, or what is called a water waste preventing cistern. This holds a charge of two gallons, the whole of which runs into the closet when the valve is pulled. The mechanical arrangement of this cistern is usually as follows: a spindle valve guards the opening of the flushing pipe going to the pan, the spindle valve is connected with a lever to which is attached a chain and ring; on pulling the chain, the spindle valve is raised and the water rushes out. The supply pipe is connected with the usual floating ball cock arrangement; when the cistern is full the ball cock floats up and shuts off the supply, when the cistern is empty the ball falls and the supply is opened. It must also be noted, that the apparatus connected with the spindle valve, by which the cistern is emptied is so arranged, that when the chain is pulled, the ball is also lifted and prevented from descending, so that until all the water is run out of the small cistern, water from the supply pipe does not enter. In this way also there is no chance of contamination by any foul gas which has made its way into the waste preventer. It may be necessary to observe that the waste preventer cistern must be a sufficient height above the closet to ensure a good flush, the writer has known them placed almost at the seat level.

(173) *Soil Pipes.*

The best material for soil pipes is lead. Lead soil pipes used formerly to be seamed, that is to say, each piece of the pipe was made by taking a long strip of lead, rolling it into a cylinder and joining the two edges by a seam. In this way there were not alone the usual transverse joints between the different portions of the soil pipe but also a seam or joint down the middle. Experience has amply shown that seamed pipes are liable to open, and they are now replaced by "drawn pipes" in which there are no longitudinal seams.

The diameter of a soil pipe should be at least 4 inches; its best position is outside the house, not inside; nevertheless a pipe carried inside is not a source of injury providing the joints are tight; in many instances the soil pipe must be carried inside. The next best material for a soil pipe is iron, but this is not suitable for inside pipes from the difficulty in making the joints absolutely perfect. Zinc soil pipes rapidly corrode and are therefore undesirable. The soil pipe should be ventilated; this is best done by carrying or rather continuing the soil pipe full bore without curves or bends to a few inches above the roof-ridge. It may be protected from the entrance of dirt by a perforated conical cap fixed by wires so as to stand well off the mouth, otherwise if placed close to the opening of the pipe, there will be obstruction of air current.

SECTION VI.

NUISANCES.

ORDINARY

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CHAPTER XX.

ORDINARY NUISANCES DEALT WITH BY SANITARY AUTHORITIES.

(174) *Distinction between Private and Public Nuisances.*

THE word nuisance has various meanings according as it is used in a popular or legal sense.

Its primary meaning is annoyance, inconvenience, or some actual injury. Blackstone said "Nuisance, *nucumentum*, or annoyance, signifies anything which worketh hurt, inconvenience or damage."

In a legal sense nuisances are of two kinds, public and private; the latter are defined as "anything done to the hurt, or annoyance of the lands, tenements and hereditaments of another." They are those for which a private individual has an action, according to the axiom that "the law gives no private remedy for anything but a private wrong;" hence these classes of nuisances, such for example as blocking up a private way, injury to a man's garden fence, and many others can neither be remedied by indictment nor under the Public Health or Sanitary Acts; they have their own peculiar remedy. On the other hand, public or common nuisances are species of offences against the public order and economical regimen of the State; they are such as annoy the whole community in general and not merely some particular person.

Of public nuisances only a certain class are contemplated by the Sanitary Acts, viz. those in which more or less injury to health, may be proved or inferred as likely to occur. In some cases also though a nuisance in a Public Health sense may be proved, yet there is no remedy under the Acts themselves, for example in a recent case, a Sanitary Authority attempted to abate in the usual way by notice and following magistrate's order, a nuisance arising

from the depositing tanks and other sewage works of a neighbouring authority, but the magistrate's order was quashed by the Court of Appeal; in the course of the judgment, Justice Wills said:[1]

"In our opinion the provisions section 91—98 have no application to sewage works constructed under the powers of section 27 Public Health Act, 1875. We think the words of section 91 do not include them, and we think were not meant to include them. It is clear that the expresssion 'premises in such a state as to be a nuisance' has not the wide application claimed for it by the respondents, who say that it is answered by any premises on which a nuisance exists. If that were so the enumeration of, at all events, the several kinds of nuisances specified under heads 2, 3, 4, and 6 would be unnecessary. We do not attempt to define every class of case to which the first head applies, but we think it is confined to cases in which the premises themselves are decayed, dilapidated, dirty or out of order; as for instance, where houses have been inhabited by tenants whose habits and ways of life have rendered them filthy or impregnated with disease, or where foul matter has been allowed to soak into walls or floors, or where they are so dilapidated as to be a danger to life and limb. It is a significant fact that under the second head the various receptacles for running or stagnant water stop with drains which by the interpretation clause are not sewers, and to take broader and higher ground, it seems to us incredible that when the legislature had entrusted the local boards with a most difficult and thankless task, in the execution of which there were certain to be, as there have been in fact, a proportion of failures, involving perhaps a cost to the district of tens, and even hundreds of thousands of pounds, and taxing to the utmost resources of mechanical art and engineering skill to set them right, a jurisdiction should be conferred upon two magistrates, with an appeal to a recorder or to a bench of justices at quarter sessions, to substitute their judgment of the mode in which, and the cost at which the mischief should be cured, for that of the local board and their skilled advisers."

When the interests are large, the case important, it is also neither usual nor advisable to seek a summary remedy under the Sanitary Acts, but to proceed by indictment or to obtain in the superior Court an injunction. For example, the pollution of a river, the

[1] Q.B., L.T., vol. lx. N.S. 42.

faulty disposal of sewage, nuisance arising from large manufactories, and similar matters which injure or aggrieve a large section of the community are most effectually and permanently dealt with in the manner indicated and not in the simple way provided by the Public Health and other acts.

The ordinary daily routine of a sanitary officer is however for the most part taken up, in discovering nuisances under the Health Statutes, and applying the legal remedy provided by them, and it is essential that he should possess a clear conception of "nuisance" considered from a legal stand-point as set forth in certain leading cases.

(175) *Leading Cases as to Nuisance.*

In the case of *the Great Western Railway Company v. Bishop*, a complaint was made under 18 and 19 Vic., c. 121. s. 8 against the company, in respect of a nuisance alleged to exist in and upon their premises, viz. a railway bridge. It was proved that during rainy weather, and for some time afterwards, water in a dirty state percolated through the bottom of the bridge which was formed of wooden planks and fell upon persons passing along the street. The railway company appealed, and it was held, "That although there might be a nuisance in respect of which the appellants were liable to be indicted, they were not liable to be proceeded against under the 18th and 19th Vict. c. 121, as the word 'nuisance' in section 8 must be read in the sense injurious to health and the percolation of water as above mentioned could only be said to be indirectly a nuisance injurious to health."

This judgment has however been somewhat modified by the case of the Bishop Auckland Sanitary Authority, *v.* the Bishop Auckland, Iron and Steel Company (L. J. R. 52. p. 38.)

Complaint was made to justices under the Public Health Act, section 91 (subs. 4) against the Iron Company in respect of an alleged nuisance occasioned by an accumulation of cinder refuse which gave off smoke and gas. The justices found as a fact that the matter complained of was a nuisance, but was not injurious to health. But the superior Court held that nevertheless they ought not to have refused to convict, *as the nuisance was of a kind which might be injurious to health, and it was not necessary in such cases under the above provision to prove that it was in fact so.*

In the course of the judgment Mr. Justice Stephen said, 'I should say that the words in the section 'nuisance or injurious to health,' cannot mean the same as 'nuisance injurious to health,' and the proper way to interpret them is to take them in their natural sense, viz., something which interferes with comfort or is injurious to health. A man might catch a deadly disease without having been exposed to a nuisance, or there might be a nuisance existing which did not injure his health or affect his comfort. There is the recent case of Banbury *v.* Page, which seems to fully bear out the view that I take, where under section 47, Public Health Act, 1875, the offence of keeping swine so as to be a nuisance was held to be complete without any evidence of there being injury to health caused thereby."

(176) *Nuisances under the* 91*st Section of the Public Health Act,* 1875.

The nuisances under the 91st section of the Public Health Act are those which were in force at the time of the Act passing, by virtue of similar clauses in the Nuisance Removal Act of 1855 and the Sanitary Act of 1866, both of which Acts are in force in the metropolis, but repealed as to the rest of the country. The nuisances enumerated are:—

1. Insanitary premises.
2. Foul pools, ditches, gutters, watercourses, privies, urinals, cesspits or drains, or ashpits.
3. Animals kept improperly.
4. Unwholesome accumulations or deposits.
5. Overcrowding of the whole or part of a house.
6. Factories or workshops not already under the operation of any general Act for the regulation of factories or bakehouses kept in an unclean state or overcrowded, or not properly ventilated.
7. Fireplaces or furnaces in manufacturing operations generally, which do not so far as practicable consume their own smoke.
8. Chimneys, not being that of a private dwelling, sending forth black smoke in such a quantity so as to be a nuisance.

1. *Any premises in such a state as to be a nuisance and injurious to health.*—It is under this definition that nine-tenths of the

sanitary orders are issued. The definition may fairly comprise such nuisances as follows:—

Leaky roofs.

General repair of a dwelling.

Dampness of the walls or basement of the dwelling.

General dirtiness of walls, staircases, and floors.

Nuisances from bad paving of yards.

Nuisances so frequently arising in dwellings in towns that are not detached, of the products of combustion of the neighbouring chimney leaking through defective flues into the adjoining living-room of either the same or the adjoining house.

Old rat runs.

Foundations saturated with filth.

Nuisances connected with the water supply, that is (*a*) absence; (*b*) polluted; (*c*) improper connection with the closet.

Nuisances from defective fittings of sinks or closets.

Nuisances from want of ventilation, and a number of others.

2. *Nuisance from drains, cesspits, and the like.*—In this category the fact only has to be proved, and whether, for example, a drain (see *House Drains*, pp. 183—188) or a cesspit is proper or improper, a nuisance or not, is entirely a question of fact, which the Medical Officer of Health is the proper person to decide.

3. *Any animal so kept as to be a nuisance or injurious to health.*—The reader is referred to the special sections treating of pig-keeping, of stables, of cow-keeping, &c.

4. *Deposits*—Under this subsection manure heaps and offensive deposits generally can be dealt with, but it is necessary to look carefully at the exception in the latter part of Section 91, viz., that no penalty is to be imposed on any person in respect of any accumulation or deposit necessary for the effectual carrying on any business or manufacture, if it be proved to the satisfaction of the Court that the accumulation or deposit has not been kept longer than is necessary for the purposes of the business or manufacture, and that the best available means have been taken for preventing injury thereby to the public health.

As an example of the kind of cases which may arise, a magisterial decision may be cited with reference to a deposit of manure at a manure merchant's premises in Chelsea.[1] The defence was that

[1] *Public Health*, vol. ii. 124.

the defendant, being a manure merchant, and that his business not being scheduled as an "offensive trade," could not be interfered with by the vestry, because at that particular season of the year, owing to the occupation of farmers, and the difficulty of obtaining barges, there had been a larger and longer accumulation of manure than ordinary. The magistrate (Mr. D'Eyncourt), in the course of an exhaustive judgment, reviewed the facts, and said it was proved that the accumulation of manure on the wharf was from 180 to 200 cubic yards in extent. This was within ninety yards of houses. There was a difference of opinion between the medical experts who had given evidence in the case, but he had come to the conclusion that the heap of manure was a nuisance, and its actual removal must be very offensive. It might be true, to some extent, that the trade could not be carried on unless the practice of the defendant was allowed, but with that he had nothing to do; and he accordingly made an order with costs for the abatement of the nuisance.

In dealing with such deposits as the above in connection with a business, there will be mainly two things for the officer of a sanitary authority to consider, viz., whether the accumulation or deposit is kept longer than necessary, and whether the best available means have been adopted to prevent any injury to the public during its retention. All this is a question of fact, and each particular case must be dealt with on its merits.

5. *Overcrowding.*—In dealing with overcrowding, the Medical Officer of Health has not to depend entirely upon his own judgment, but rather to follow precedent. The amount of cubic space allowed by the Local Government Board in various regulations as to houses let in lodgings, is 400 cubic feet each person for rooms occupied day and night, and 300 cubic feet for each person for rooms legitimately occupied as sleeping-rooms only, two children under twelve counting as one adult. It requires very good ventilation for this space to be really enough—in badly ventilated rooms the space is not sufficient—and the rule of allowing two children to count as one adult is a mistake, the quick respiration of the young making up for chest capacity, besides which, in the case of very young children, the rule is that all excreta is passed in the room, and there is thus an additional defilement of the atmosphere.

The interpretation of the old Acts[1] was that the overcrowding must be by two different families, but the words, "whether or not members of the same family" were added to the Public Health Act (they are not in corresponding clause of Sanitary Act of 1866), to clear up any difficulty of interpretation.

6. *Factories, &c.*—The Factory and Bakeshop Acts are so comprehensive that little or no use has been made of this subsection.

7 and 8. *The Smoke Clauses.*—There are several things to be considered here. In the first place it is evident that any kind of engine, such for example, as a steam-engine working a dynamo, although not in a factory, but on strictly private premises, comes under the subsection, although probably in a legal case, the barrister for the defence would argue that the disjunctive, "or any manufacturing or trade process whatsoever," governed the section, and that the section was only applicable to a trade process, and not to a person manufacturing his own electricity for the supply of his own house. The author is, however, decidedly of opinion that the words, "*which is used for working engines by steam,*" should be taken in their natural meaning.

In the second place, it is enacted that the chimney of any but a private dwelling-house, sending forth black smoke in such quantity as to be a nuisance, can be dealt with under the section.

There may be easily cases arise rendering it difficult to determine whether a chimney is that of a private dwelling or not. The cases which will present difficulty will be those in which a manufacturing operation is carried on in a house used in part as a residence, or in a shed or annex to a private house. Here again it will be mainly a question of fact for the magistrate to determine. The smoke under this subsection must be "black," and in appreciable quantity. If the offender should by means of a steam-blower, or other means, turn the vapour into white smoke, or in some way colour the smoke, it is obvious the section does not apply, even though the nuisance may be aggravated by such means, as indeed has happened in the author's own experience.

Lastly, in all these cases it will be absolutely necessary, if legal action be contemplated to enforce an order of the sanitary authority, to prove by expert evidence that the fireplace or furnace is not of

[1] That is, N. Rem. Act, 1855, and Sanitary Act, 1866, still in force in the metropolis.

the best construction, or that known appliances have not been made use of to consume the smoke or to prevent its emanation.

(177) *Offensive businesses specifically mentioned in the Public Health and Sanitary Acts.*

Certain classes of trades which produce offensive effluvia are specifically mentioned in the Public Health Act, 1875, sections 112–115, and the same trades are enumerated in the slaughter-houses, &c., Metropolis Act, 1874, 37 & 38 Vict., c. 67. These trades are :—boiling offal, or blood ; boiling, burning, or crushing bones ; the trade of a fellmonger ; the trade of a tallow melter ; the trade of a soap maker ; the trade of a tripe boiler ; the trade of a slaughterer.

Power is given by the above Acts both in the metropolis and in the country, to the London County Council and Urban Sanitary Authorities, to make bye-laws regulating the trades or businesses mentioned, or as "to any offensive trades established with their consent." (Public Health Act, 1875, section 113.)

In the Metropolis Slaughter-House Act, the trade of a "knacker" is also specifically mentioned, and any business the local authority (which in this case is the London County Council) may wish to add to the list of offensive businesses and to regulate by bye-law, must be declared so by order and be duly confirmed by the Local Government Board (section 3). It may also be mentioned that section 115 of the Public Health Act, 1875, enabling an Urban Sanitary Authority to take proceedings on the ground of nuisance with respect to an offensive trade *without* their district is in force in the Metropolis.

(178) *Blood Drier, Blood Albumin, Blood Boiling.*

In the manufacture of blood and in the drying of blood there are various sources of nuisance, of which the following are the chief :—

(1) Effluvia from putrid blood arising from the exhausted clots prior to removal.

(2) The disagreeable faint smell proceeding from the yard and premises, especially when the most scrupulous cleanliness has not been observed.

(3) Effluvia from other processes, such as blood boiling, or manufacture into manure, often carried on in the same premises.

The business of a blood drier is regulated in the Metropolis as follows :—

LONDON COUNTY COUNCIL.

THE SLAUGHTERHOUSES, &c. (METROPOLIS), ACT, 1874, 37 & 38 *Vic.*, c. 67.

BYE-LAWS for regulating the conduct of the business of a Blood Drier, and any business in which blood or any of the constituent parts of blood is used, provided that heat be in any way applied or used to the same, and that, whether such blood or any of the constituent parts thereof be or be not at the time of the application or use of such heat diluted or mixed with any other substance ; and the structure of the premises on which such business is being carried on ; and the mode in which application is to be made for sanction to establish such business anew ; within the limits of the Metropolis (except the City of London and the liberties thereof).

In pursuance of the Slaughterhouses, &c. (Metropolis), Act, 1874, by which the Metropolitan Board of Works[1] are constituted the Local Authority for the Metropolis (except the City of London and the liberties thereof), the said Metropolitan Board of Works[1] do hereby make the following Bye-Laws :—

Bye-Laws for Regulating the Conduct of the Business.

1. Every Blood Drier shall cause all blood brought upon his premises to be brought in closed vessels or receptacles constructed of galvanized iron or other non-absorbent material.

2. Every Blood Drier shall cause every process of his business (except the drying and packing processes) to be carried on in a building properly paved with asphalte, concrete, or other suitable jointless material, having walls covered to a height of at least six feet with hard, smooth, and impervious material.

3. Every Blood Drier shall cause every process of his business in which any offensive effluvia, vapours, or gases are generated, to be carried on in such manner that no offensive effluvia, vapours, or gases shall escape into the external atmosphere ; and he shall cause all such offensive effluvia, vapours, or gases to be effectually destroyed.

4. Every Blood Drier shall cause all blood, blood-clot, or any refuse, residue, or other matter from which offensive effluvia or vapours are evolved or are liable to be evolved, to be placed in properly closed receptacles, or to be otherwise dealt with in such manner as to prevent any offensive effluvia or vapours therefrom escaping into the external atmosphere.

5. Every Blood Drier shall cause the floor of every place in which any process of the business (except the drying and packing processes) is carried on to be thoroughly cleansed with water, at least once in twenty-four hours ; and he shall cause the premises to be constantly provided with an adequate supply of water for the purpose.

6. Every Blood Drier shall cause every inner wall of the premises on which his business is carried on to be kept at all times thoroughly clean and in good order and repair. He shall (except as is hereinafter provided) cause every such wall or part of such wall which is not covered with hard, smooth, and impervious material, and every ceiling to be thoroughly washed with hot lime-wash in the first week of each of the months of March and September in every year ; provided always that this requirement shall not be deemed to extend to any chamber used for the purpose of drying albumen.

7. Every Blood Drier shall cause every vessel, receptacle, utensil, or instrument provided or used upon, or in connection with, the premises on which his business may be carried on, to be kept at all times thoroughly clean, so as to prevent the emission of any offensive smell from such vessel, receptacle, utensil, or instrument.

8. Every Blood Drier shall afford access to every part of the premises on which

[1] Now London County Council.

his business is carried on to every Member and Officer of the Board, authorised in writing under the hand of the Clerk of the said Board, at any reasonable time during the hours within which such business may be carried on.

9. Every person offending against any of the foregoing Bye-Laws shall be liable for every such offence to a penalty of Five pounds; and in the case of a continuing offence to a penalty of One pound for every day during which the offence may be continued after the conviction for the first offence.

10. Every Court of Summary Jurisdiction, as defined in the Slaughterhouses, &c. (Metropolis), Act, 1874, may, as a penalty for the breach of any of the foregoing Bye-Laws, by summary Order, suspend, or deprive any person altogether of the right of carrying on the business of a Blood Drier.

Bye-Laws for Regulating the Structure of the Premises.

11. Every Blood Drier shall cause the floor of the yard and every part of his premises in which any process of his business (except the drying and packing processes) is carried on, to be properly paved with asphalte, concrete, or other suitable jointless material, laid upon a suitable bottom of at least four inches in thickness, and such floor to have a proper slope towards a channel or gully; and shall cause his premises to be effectually drained by adequate drains communicating with a public sewer. The drains shall be properly trapped, and the entrances thereto shall be covered with fixed gratings, the bars of which shall not be more than three-eighths of an inch apart.

12. Every Blood Drier shall cause the inner walls of every building in which any process of his business (except the drying and packing processes) is carried on, to be covered to a height of at least six feet with hard, smooth, impervious material.

13. Every Blood Drier shall cause his premises to be provided with appliances capable of effectually destroying all offensive effluvia, vapours, or gases arising in any process of his business, or from any material, residue, or other substance which may be kept or stored upon his premises.

14. Every Blood Drier shall cause all needful works and alterations to the premises to be forthwith done and executed as and when the same shall become requisite, but shall not allow any alteration whatsoever to be made in respect of the structure of the premises, without the consent of the Board.

15. Every person who shall not comply with any of the foregoing Bye-Laws relating to the structure of the premises shall be guilty of an offence, and shall be liable, for every such offence, to a penalty of Five pounds, and in the case of a continuing offence, to a penalty of One pound for every day during which the offence may be continued after the conviction of the first offence. Provided always that the foregoing Bye-Laws for regulating the structure of the premises shall not, until after the expiration of twelve months from the date of the confirmation of the Bye-Laws, be deemed to apply to any premises where at such date the business of a Blood Drier may be carried on.

Bye-Laws for Regulating the mode of Application for Sanction to new Establishment of the Business.

16. Every person who may apply to the Board for their sanction to establish anew the business of a Blood Drier, shall furnish with the application a plan of the premises and sections of the buildings in which it is proposed to carry on such business, such plans and sections being drawn to a scale of a quarter of an inch to the foot, and showing the provision made, or proposed to be made, for the proper conduct of such business, and for the drainage, ventilation, and water supply of such premises, and shall also furnish a key plan of the locality, showing the buildings and streets within one hundred yards of the premises, drawn to a scale of five feet to the mile.

(179) *Fat Melting, Dip Candle Making.*

The materials used are kitchen stuff and fat collected from various materials.

The fat is melted either in pans:—(*a*) heated by the open fire; (*b*) by free steam and sulphuric acid; (*c*) in pans, steam jacketed.

The sources of nuisance are;—(1) The storage of the fat (this is often spread out to sweeten); (2) melting the fat; (3) ladling it out; (4) storage of greaves, *i.e.*, residue; (5) general filth. Remedies, proper storage. "The method of preventing nuisance commences at the slaughter-houses. As soon as the fat is removed from the animals it should be laid on racks, and it should not be packed until quite cold and hard" (Ballard).

The method of rendering has much to do with the creation of nuisance: in towns the only method permissible will be by free steam or in steam-jacketed pans. But this method is not a favourite with the manufacturers, for the greaves, which are worth £16 a ton, are thereby lost. There is a method of consuming the vapours even with free rendering. The fire is applied with air to the top of the pan and thus the offensive vapour is burned up. This is only successful with a good draught such as can be obtained by a high chimney shaft.

Bye-laws regulating fat melting in the Metropolis are as follows:—

LONDON COUNTY COUNCIL.

The Slaughterhouses, &c. (Metropolis), Act, 1874, 37 & 38 *Vic.*, c. 67.

Bye-Laws for regulating the conduct of the business of a Fat Melter, or Fat Extractor, that is to say, any business in which Fat is melted, rendered, extracted from any material, or remelted; and the structure of the premises on which such business is being carried on; and the mode in which application is to be made for sanction to establish such business anew; within the limits of the Metropolis (except the City of London and the liberties thereof.)

In pursuance of the Slaughterhouses, &c. (Metropolis), Act, 1874, by which the Metropolitan Board of Works[1] are constituted the Local Authority for the Metropolis (except the City of London and the liberties thereof), the said Metropolitan Board of Works,[1] do hereby make the following Bye-Laws:—

Bye-Laws for Regulating the Conduct of the Business.

1. Every Fat Melter or Fat Extractor shall cause every process of his business in which any offensive effluvia, vapours, or gases are generated, to be carried on in such manner that no offensive effluvia, vapours, or gases shall escape into the external atmosphere, but shall cause all such offensive effluvia, vapours, or gases to be effectually destroyed.

2. Every Fat Melter or Fat Extractor shall cause all material used or offensive material or refuse from the boiling pans, and all refuse, residue, or other matter from which offensive effluvia, vapours or gases are evolved or are liable to be evolved, to be placed in properly closed receptacles, or to be otherwise dealt with in such manner as to prevent any offensive effluvia, vapours, or gases therefrom escaping into the external atmosphere.

[1] This now to be read "London County Council."

3. Every Fat Melter or Fat Extractor shall cause all scraps or litter composed of matters liable to become decomposed, to be constantly gathered or swept up and placed in proper covered receptacles.

4. Every Fat Melter or Fat Extractor shall cause the floor of every place in which any process of the business is carried on, to be kept thoroughly cleansed, and he shall cause the premises to be constantly provided with an adequate supply of water for the purpose.

5. Every Fat Melter or Fat Extractor shall cause every inner wall of the premises on which his business is carried on to be kept at all times thoroughly clean and in good order and repair. He shall cause every inner wall and every ceiling in every part of his premises where any process of his business may be carried on, to be thoroughly washed with hot lime-wash, at least twice in every year, that is to say, in the months of March and September, and likewise as often as may be necessary for the purpose of keeping such part of the premises in a cleanly and wholesome state.

6. Every Fat Melter or Fat Extractor shall cause every vessel, receptacle, utensil, or instrument provided or used upon, or in connection with, the premises on which his business may be carried on, to be kept, when not actually in use, at all times thoroughly clean, so as to prevent the emission of any offensive smell from such vessel, receptacle, utensil or instrument.

7. Every Fat Melter or Fat Extractor shall afford access to every part of the premises on which his business is carried on to every Member and Officer of the Board, authorised in writing under the hand of the Clerk of the said Board, at any reasonable time during the hours within such business may be carried on.

8. Every person offending against any of the foregoing Bye-Laws shall be liable for every such offence to a penalty of Five pounds ; and in the case of a continuing offence to a penalty of One pound for every day during which the offence may be continued after the conviction for the first offence.

9. Every Court of Summary Jurisdiction, as defined in the Slaughterhouses, &c. (Metropolis), Act, 1874, may, as a penalty for the breach of any of the foregoing Bye-Laws, by Summary Order, suspend or deprive any person altogether of the right of carrying on the business of a Fat Melter or Fat Extractor.

Bye-Laws for Regulating the Structure of the Premises.

10. Every Fat Melter or Fat Extractor shall cause every floor upon which any process of his business is carried on, in any part of his premises, to be properly covered with a layer of concrete, or other suitable jointless impervious material, laid (in the case of a ground floor) upon a suitable bottom of at least four inches in thickness. He shall cause every such floor to have a proper slope towards a channel or gully ; and shall cause every part of his premises wherein any such floor may be constructed to be effectually drained by adequate drains communicating with a public sewer. He shall also cause every drain to be properly trapped, and the entrance thereto to be covered with a fixed grating, the bars of which shall not be more than three-eighths of an inch apart.

11. Every Fat Melter or Fat Extractor shall cause his premises to be provided with appliances capable of effectually destroying all offensive effluvia, vapours or gases arising in any process of his business, or from any material, residue, or other substance which may be kept or stored upon his premises.

12. Every Fat Melter or Fat Extractor shall cause all needful works and alterations to the premises to be forthwith done and executed as and when the same shall become requisite, but shall not allow any alteration whatsoever to be made in respect of the structure of the premises, without the consent of the Board.

13. Every person who shall not comply with any of the foregoing Bye-Laws relating to the structure of the premises shall be guilty of an offence, and shall be liable, for every such offence, to a penalty of Five pounds, and in the case of a continuing offence, to a penalty of One pound for every day during which the offence may be continued after the conviction for the first offence. Provided always that the foregoing Bye-laws for regulating the structure of the premises shall not until after the expiration of six months from the date of the confirmation of the Bye-Laws be deemed to apply to any premises where at such date the business of a Fat Melter or Fat Extractor may be carried on.

Bye-Laws for Regulating the mode of Application for Sanction to New Establishment of the Business.

14. Every person who may apply to the Board for sanction to establish anew the business of a Fat Melter or Fat Extractor, shall furnish with the application a plan of the premises and sections of the buildings in which it is proposed to carry on such business, such plans and sections being drawn to a scale of a quarter of an inch to the foot, and showing the provision made or proposed to be made, for the drainage, lighting, ventilation, and water supply of such premises, and shall also furnish a key plan of the locality, showing the buildings and streets within one hundred yards of the premises, drawn to a scale of five feet to the mile.

(180) *Bone Boiling.*

This is peculiarly offensive, and the vapours will travel a long distance. The storage of the material and the conveyance to the factory are all possible sources of offence. At Deheer's manufactory, Hull, the process is conducted in a closed building, and the vapours from a covered boiling pan are conducted by a pipe passing through the wall of the building to an ordinary worm condenser outside. Such vapours as are not thus condensed go through a furnace fire. The result Dr. Ballard found not to be perfect, for the vapours escaped through cracks, and the condensed water passing into the drains at a high temperature would burst up through imperfectly sealed traps.

There is also nuisance after boiling, for recently boiled bones when heaped together evolve an offensive steam possessing a musty ammoniacal odour.

In all such operations as bone boiling there will be less nuisance if the operation is conducted in steam-jacketed pans than in those on which the fire plays direct, in the latter case the heat towards the end of the operation is apt to be raised too high, and then there is the production of empyreumatic stinking products.

The regulations which should be made as to this business are given, page 254.

(181) *Soap Boiling, Soap Making.*

In the manufacture of soap, various fats are boiled with soda lye, or if the manufacture be that of soft soap, the fats are boiled with potash lye ; in this last manufacture various kinds of oils, such as fish oil, seal oil, rape oil, white oil, linseed or cotton oil, are used.

The sources of nuisance are almost entirely due to the fats used, so that the same remedies are to be applied as detailed in fat melting, &c.

(182) *Manufacture of Manure.*

This is a somewhat indefinite appellation. Manure may be simply crushing bones, and manufacturing into superphosphate by the addition of sulphuric acid; in this case acid and irritating emanations may arise, unless the products are sufficiently condensed, or unless the products are conveyed by means of a tall chimney shaft into the upper regions of the atmosphere; or it may be the drying of condemned fish, or meat, by a steam-jacketed revolving pan, as practised on the east side of the Thames below Woolwich; manure is also manufactured from sewage sludge, and from a variety of other refuse. Nevertheless whatever the manufacture the general regulations are pretty well the same as those which may be applied to trades *ejusdem generis.*

In the metropolis the following bye-laws are in force governing the three or four trades just treated of:—

LONDON COUNTY COUNCIL.

THE SLAUGHTERHOUSES, &c. (METROPOLIS) ACT, 1874, 37 *and* 38 *Vic.*, *c.* 67.

BYE-LAWS for the regulation of the conduct of the business of a Blood Boiler, Bone Boiler, Manure Manufacturer, Soap Boiler, or Tallow Melter, within the limits of the Metropolis, as defined by this Act (except the City of London and the liberties thereof), and the structure of the premises on which any such business may be carried on.

In pursuance of the above Act, by which the Metropolitan Board of Works[1] is constituted the Local Authority of the Metropolis, as defined in the said Act (except the City of London and the liberties thereof), the said Metropolitan Board of Works[1] (for the purposes of these Bye-laws called the "Board"), doth hereby make the following Bye laws:—

Bye-Laws for Regulating the Conduct of the Business.

1. Every Blood Boiler, Bone Boiler, Manure Manufacturer, Soap Boiler or Tallow Melter, shall cause every boiler, mixer, or other vessel from which any offensive or noxious vapour or gas may be evolved in any operation or process of his business, to be properly covered, and in all other respects to be so constructed and used as to cause all such vapour or gas to be effectually conveyed into, or through, a furnace fire, or otherwise to be prevented from escaping into the external atmosphere.

2. Every Blood Boiler, Bone Boiler, Manure Manufacture, Soap Boiler, or Tallow Melter, shall cause every room, chamber, or other place which may be used on or in connection with the premises where his business is carried on, for the purpose of receiving or storing any manufactured product, residue, or any other matter, from which any offensive vapour or gas may be evolved, to be furnished with suitable appliances, so constructed and used as to effectually prevent the escape of such vapour or gas into the external atmosphere. He shall at all times adopt such precautions and employ such means as may be necessary to cause all such vapour or gas to be conveyed into or through a furnace-fire or to be so condensed as to be effectually destroyed.

3. Every Blood Boiler, Bone Boiler, Manure Manufacturer, Soap Boiler, or Tallow Melter, shall cause all material, manufactured product, residue, refuse, or other

[1] This is now to be read "London County Council."

matter used on or in connection with the premises where his business is carried on, from which any offensive vapour or gas may be evolved, to be received or stored in rooms, chambers, or other places, constructed so that there may be no opening from such rooms, chambers, or other places into the external atmosphere.

4. Every Blood Boiler, Bone Boiler, Manure Manufacturer, Soap Boiler, or Tallow Melter, shall afford free access to every part of the premises where his business is carried on, to every Member and Officer of the Board, authorised in writing under the hand of the Clerk of the said Board, at any reasonable time during the hours within which such business may be in operation.

5. Every person offending against any of the foregoing Bye-laws shall be liable for any such offence to a penalty of £5, and in the case of a continuing offence, to a penalty of £1 for every day during which the offence may be continued after the conviction for the first offence.

6. Every Court of Summary Jurisdiction, as defined in the Slaughter-houses, &c. (Metropolis), Act, 1874, may, by Summary Order, as a penalty for the breach of any of the foregoing Bye-laws, suspend or deprive any person altogether of the right of carrying on the business of a Blood Boiler, Bone Boiler, Manure Manufacturer, Soap Boiler, or Tallow Melter.

Bye-law for Regulating the Structure of the Premises.

7. Every Blood Boiler, Bone Boiler, Manure Manufacturer, Soap Boiler, or Tallow Melter, shall cause every room, chamber, or other place which may be used on or in connection with the premises where his business is carried on, for the purpose of receiving or storing any manufactured product, residue, or other matter from which any offensive vapour or gas may be evolved, to be constructed so that there may be no opening from such room, chamber, or place into the external atmosphere.

(183) *The Trade of a Fellmonger.*

The fellmonger's business is to prepare skins for the leather dresser. He receives either recent or foreign skins, and the process is slightly different as to whether the one or the other has to be treated.

Fresh Skins.—These are beaten with a mallet to free them from dirt, and then soaked and washed in water. The skins are then limed (the object of liming is to detach the hair); the skin is laid with the hair undermost, and milk of lime is worked into the raw or fleshy surface of the skin. This process finished, the skins are hung up; and when it is found that the wool can easily be detached, the wool is removed by hand.

The skins denuded of wool are termed "pelts." The pelts are thrown into a pit containing milk of lime, and from this pit go direct to the leather dresser.

Foreign skins are hard and dry, and first require soaking. The "burrs," with which the wool is often covered, are also removed by a special machine. The wool is not loosened by liming, but is removed by "the tainting process," that is, a certain decomposition occurs which loosens the wool, and when this stage is reached the wool as before is removed by hand.

The chief nuisance is the storing of large quantities of skin, none of which is absolutely free from adherent portions of flesh, but the other operations can all be done without the creation of nuisance. It is true that large quantities of skins undergoing the "tainting" process smell slightly, but the smell seldom extends beyond the sheds or works. The chief and essential thing is to avoid cause of offence in the storing of the fresh skins.

(184) *Gut Scraping—Gut Spinning—Preparation of Sausage Skins.*

These trades are all of a kin. Gut scraping is in the larger establishments done by women. The intestine is scraped on a bench by a wedge-shaped piece of wood, all the interior soft parts being in this way detached, and pass along to go out of the cut end; only the peritoneum and a little of the muscular structure of the gut is left. This is the whole operation for sausage skins.

For ordinary catgut, lengths of the scraped gut are sewn together with needle and thread. They are then spun by means of a spinning wheel. Gut spinning is therefore only the twisting of the prepared gut into a cord. The materials used are the small intestines of hogs and sheep. The intestine of the latter measures from 25 to 30 yards, that of the hog about 20 yards. The gut is first, as a preliminary operation, freed by washing from its contents.

With regard to these operations, Ballard says:—

"Speaking generally, gut scraping and gut spinning establishments are the most intolerable of nuisances wherever they may chance to be located. Within the workshops the stench is inconceivably horrible: few persons unaccustomed to it could bear to remain for a single minute in some scraping rooms that I have visited: I myself have had sometimes a difficulty to restrain vomiting and to carry on the inquiries I was bent upon. The stench, after I have been in some of them for twenty minutes or half an hour, has so pertinaciously attached itself to my clothing and hair, that only repeated ablutions have removed the odour from my hair; my clothing has retained the stench for days. It spreads from the workshop and yard all round the neighbourhood, and often gives rise to such loud complaints that local

authorities in some towns have insisted upon the entire removal of them."

As an example of the regulations necessary to be enforced the following byelaws in force in the metropolis may be quoted :—

LONDON COUNTY COUNCIL.

THE SLAUGHTERHOUSES, &c. (METROPOLIS), ACT, 1874, 37 *and* 38 *Vic.*, c. 67.

BYE-LAWS for regulating the conduct of the business of a Gut Scraper, that is to say, any business in which gut is cleansed, scraped, or dealt with otherwise than for the manufacture of cat-gut: and the structure of the premises on which such business is being carried on; and the mode in which application is to be made for sanction to establish such business anew, within the limits of the Metropolis (except the City of London and the liberties thereof).

In pursuance of the Slaughterhouses, &c. (Metropolis) Act, 1874, by which the Metropolitan Board of Works [1] are constituted the Local Authority for the Metropolis (except the City of London and the liberties thereof), the said Metropolitan Board of Works [1] do hereby make the following Bye-Laws :—

Bye-Laws for Regulating the Conduct of the Business.

1. Every Gut Scraper shall cause all gut, and every other offensive material which may at any time be brought or kept upon the premises, to be so brought or kept in close vessels or receptacles; and shall in all other respects adopt such precautions in the bringing or keeping of any such gut or other material upon the premises as effectually to prevent the emission of any offensive smell from such gut or other material.

2. Every Gut Scraper shall cause every vessel or receptacle which may be used for the bringing, keeping or manipulation of such gut or other offensive material upon the premises, to be constructed of galvanized iron or other non-absorbent material, and to be furnished with tight and close-fitting covers.

3. Every Gut Scraper shall cause his business to be so carried on, and shall in all other respects cause such precautions to be taken, as may be necessary to prevent the emission of any offensive smell into the external atmosphere from any part of the premises where such business may be carried on.

4. Every Gut Scraper shall cause all offensive gut, garbage, filth, refuse, or other offensive matter upon the premises, to be placed in proper vessels or receptacles constructed of non-absorbent materials and effectually closed.

5. Every Gut Scraper shall cause the floor of any part of the premises where gut scraping may have been carried on, and every tank, tub, vessel, or receptacle, scraping board, and other utensil or instrument which may have been in use, or which may be in a foul or offensive condition, to be effectually cleansed, and to be disinfected by the application thereto of a sufficient quantity of chloride of lime, carbolic acid, or other effectual disinfectant.

6. Every Gut Scraper shall, from time to time, as often as occasion may require, cause all garbage, filth, or refuse to be removed from his premises in properly closed vessels or receptacles, constructed of galvanized iron or other non-absorbent material.

7. Every Gut Scraper shall cause the premises on which his business is carried on to be constantly provided with an adequate supply of water, and he shall cause every part of such premises to be thoroughly washed, from time to time, as often as may be necessary, and to be kept at all times thoroughly clean.

8. Every Gut Scraper shall cause every inner wall of the premises on which his business is carried on to be kept at all times thoroughly clean and in good order and repair. He shall cause the upper part of every inner wall and also every ceiling in

[1] See previous footnotes.

every part of his premises where any process of his business may be carried on, to be thoroughly washed with hot lime-wash in the first week of each of the months of March and September, and also as often as may be necessary for the purpose of keeping such part of the premises in a clean and wholesome state.

9. Every Gut Scraper shall cause every vessel, receptacle, utensil, or instrument provided or used upon, or in connection with, the premises on which his business may be carried on, to be kept, when not actually in use, at all times thoroughly clean, so as to prevent the emission of any offensive smell from such vessel, receptacle, utensil or instrument.

10. Every Gut Scraper shall afford access to every part of the premises on which his business is carried on to every Member and Officer of the Board, authorised in writing under the hand of the Clerk of the said Board, at any reasonable time during the hours within which such business may be carried on.

11. Every person who shall not comply with any of these Bye-Laws shall be guilty of an offence, and shall be liable for every such offence to a penalty of Five pounds; and in the case of a continuing offence, to a penalty of One pound for every day during which the offence may be continued after the conviction for the first offence.

12. Every Court of Summary Jurisdiction, as defined in the Slaughter-houses, &c. (Metropolis), Act, 1874, may, as a penalty for the breach of any of the foregoing Bye-Laws, by Summary Order, suspend or deprive any person altogether of the right of carrying on the business of a Gut Scraper.

Bye-Laws for Regulating the Structure of the Premises.

13. Every Gut Scraper shall cause every floor upon which any process of his business is carried on, in any part of his premises, to be properly covered with a layer of concrete, or other suitable jointless, impervious material, laid (in the case of a ground floor, upon a suitable bottom of at least four inches in thickness. He shall cause every such floor to have a proper slope towards a channel or gully; and shall cause every part of his premises wherein any such floor may be constructed to be effectually drained by adequate drains communicating with a public sewer. He shall also cause every drain to be properly trapped, and the entrance thereto to be covered with a fixed grating, the bars of which shall not be more than three-eighths of an inch apart.

14. Every Gut Scraper shall cause the inner walls of every part of his premises within which gut scraping is carried on, to be covered with hard, smooth, impervious material, to the height of four feet at the least; and such covering shall be always kept in good repair.

15. Every Gut Scraper shall cause all needful works and repairs to the premises to be forthwith done and executed as and when the same shall become requisite, but shall not allow any alteration whatsoever to be made in respect of the structure of the premises, without the consent of the Board.

16. Every person who shall not comply with any of the foregoing Bye-Laws relating to the structure of the premises shall be guilty of an offence, and shall be liable, for every such offence, to a penalty of Five pounds, and in the case of a continuing offence, to a penalty of One pound for every day during which the offence may be continued after the conviction for the first offence.

Bye Laws for Regulating the Mode of Application for Sanction to New Establishment of the Business.

17. Every person who may apply to the Board for sanction to establish anew the business of a Gut Scraper, shall furnish with the application a plan of the premises and sections of the buildings in which it is proposed to carry on such business, such plans and sections being drawn to a scale of a quarter of an inch to the foot, and showing the provision made, or proposed to be made, for the drainage, lighting, ventilation, and water supply of such premises; and shall also furnish a key plan of the locality, showing the buildings and streets within one hundred yards of the premises, drawn to a scale of five feet to the mile.

LONDON COUNTY COUNCIL.

THE SLAUGHTERHOUSES, &c. (METROPOLIS) ACT, 1874, 37 *and* 38 *Vic.*, c. 67.

BYE-LAWS for regulating the conduct of the business of a Cat Gut Maker or Cat Gut Manufacturer, *i.e.*, a person whose business it is to manufacture articles from the gut or intestines of animals; and the structure of the premises on which such business is being carried on; and the mode in which application is to be made for sanction to establish such business anew; within the limits of the Metropolis (except the City of London and the liberties thereof).

In pursuance of the Slaughterhouses, &c. (Metropolis), Act, 1874, by which the Metropolitan Board of Works [1] are constituted the Local Authority for the Metropolis (except the City of London and the liberties thereof), the said Metropolitan Board of Works [1] (for the purposes of these Bye-Laws called the "Board") do hereby make the following Bye-Laws:—

Bye-Law for Regulating the Conduct of the Business.

1. Every Cat Gut Maker shall cause all gut, other than dried gut, and every other offensive material which may at any time be brought or kept upon the premises, to be so brought or kept in closed vessels or receptacles; and shall in all other respects adopt such precautions in the bringing or keeping of any such gut or other material upon the premises as effectually to prevent the emission of any offensive smell from such gut or other material.

He shall cause every vessel or receptacle which may be used for the bringing, keeping, or manipulation of such gut or other offensive material upon the premises, to be constructed of galvanised iron or other non-absorbent material, and to be furnished with tight and close-fitting covers.

2. No Cat Gut Maker shall, after the expiration of twelve months from the date of the publication of these Bye-Laws, open or permit to be opened any vessel or receptacle containing gut or other offensive material, or carry on or permit to be carried on, the processes of cleansing and scraping the gut, except in a chamber constructed in accordance with the requirements of the Bye-Law in that behalf herein contained, and effectually closed so as not to allow any offensive smell to escape therefrom into the external atmosphere, or into the other parts of the premises.

3. Every Cat Gut Maker, at all times while the process of cleansing or scraping any gut may be carried on, shall cause such process to be so carried on and in all other respects such precautions to be taken, as may be necessary to prevent the emission of any offensive smell into the external atmosphere from the chamber in which such process may be carried on.

4. Every Cat Gut Maker, on every day during which the processes of cleansing and scraping any gut may be carried on, shall, immediately after the completion of such cleansing and scraping, cause all offensive gut, garbage, filth, refuse, or other offensive matter retained upon the premises, to be placed in proper vessels or receptacles constructed of non-absorbent materials and effectually closed.

He shall, at the same time, cause the floor of the chamber in which any such process may have been carried on, and every tank, tub, vessel, or receptacle, scraping board, and other utensils or instrument which may have been in use during the day, or which may be in a foul or offensive condition, to be effectually cleansed, and to be disinfected by the application thereto of a sufficient quantity of chloride of lime, carbolic acid, or some other effectual disinfectant.

5. Every Cat Gut Maker shall, after the expiration of the time aforesaid, during the process of opening any vessel or receptacle, or of cleansing or scraping any gut, or of cleansing or disinfecting any close chamber or any utensil, cause the atmosphere of the close chamber wherein such process may be carried on, to be continuously drawn into a shaft and conveyed into or through a furnace fire in such a manner as to effectually consume or destroy all noxious and offensive gases or vapours which may have arisen from such process therein.

[1] To be now read "London County Council."

6. Every Cat Gut Maker shall, from time to time, as often as occasion may require, cause all garbage, filth, or refuse to be removed from his premises in properly closed vessels or receptacles constructed of galvanised iron or other non-absorbent material.

7. Every Cat Gut Maker shall cause the premises on which his business is carried on to be constantly provided with an adequate supply of water, which shall be received and stored in a cistern or other suitable receptacle, properly constructed; or, in the case of a constant supply of water, by a pipe communicating with a Water Company's main; and he shall cause every part of such premises to be thoroughly washed, from time to time, as often as may be necessary; and to be kept at all times thoroughly clean.

8. Every Cat Gut Maker shall cause every inner wall of the premises on which his business is carried on to be kept at all times thoroughly clean and in good order and repair. He shall cause every such wall and every ceiling to be thoroughly washed with hot lime-wash in the first week of each of the months of March, June, September, and December.

9. Every Cat Gut Maker shall cause every vessel, receptacle, utensil, or instrument provided or used upon, or in connection with the premises on which his business may be carried on, to be kept, when not actually in use, at all times thoroughly clean, so as to prevent the emission of any offensive smell from such vessel, receptacle, utensil or instrument.

10. Every Cat Gut Maker shall, at the expiration of the time aforesaid, cause every room, chamber, or other place which may be used on or in connection with the premises where his business is carried on, and in which any offensive vapour, gas, or fume may be evolved, to be furnished with suitable appliances, so constructed and used as to effectually prevent the escape of any of such vapour, gas, or fume into the external atmosphere. He shall at all times adopt such precautions and employ such means as may be necessary to cause every such vapour, gas, or fume to be conveyed into or through a furnace fire, or to be condensed, so as to be effectually destroyed.

11. Every Cat Gut Maker shall afford access to every part of the premises on which his business is carried on to every Member and Officer of the Board, authorised in writing under the hand of the Clerk of the said Board, at any reasonable time during the hours within which such business may be carried on.

12. Every person who shall not comply with any of these Bye-Laws shall be guilty of an offence, and shall be liable, for every such offence, to a penalty of Five pounds, and in the case of a continuing offence, to a penalty of One pound for every day during which the offence may be continued after the conviction for the first offence.

13. Every Court of Summary Jurisdiction, as defined in the Slaughterhouses, &c. (Metropolis), Act, 1874, may, as a penalty for the breach of any of the foregoing Bye-Laws, by summary Order, suspend or deprive any person altogether of the right of carrying on the business of a Cat Gut Maker.

Bye-Laws for Regulating the Structure of the Premises, which shall be complied with as regards all Buildings now used for the Business, before the expiration of twelve Calendar Months from the date of the Publication thereof; and as regards Buildings to be used hereafter, before the Business shall be commenced therein.

14. Every Cat Gut Maker shall provide, or cause to be provided, upon the premises, a chamber or chambers in which the offensive processes of the business are to be carried on, and such chamber or chambers shall be constructed in the following manner, viz.—

(*a*) The walls shall be of brick, stone, or concrete; and the walls and the ceiling shall be constructed in such manner that the atmosphere of the close chamber cannot escape into the external atmosphere.

(*b*) The windows or lights shall be of glass, not less than one-quarter of an inch in thickness, and shall be fixed in the walls or roof in such a manner as not to open, and to be air-tight, and such windows or lights shall be covered externally with a wire netting.

(c) There shall be only one doorway in a close chamber, and the door thereto shall be made to closely fit the doorway in such a manner that when shut the atmosphere of a close chamber cannot escape through such doorway.

(d) The paving shall be asphalte, Yorkshire flagstone, Stourbridge paving bricks, closely set in cement, upon a bottom of four inches of good concrete, or other suitable material; and shall be laid with a proper slope and channel towards a gully, and shall be effectually drained by an adequate drain of glazed pipes communicating with the public sewer, and properly ventilated. The drain shall be properly trapped, and be covered with a fixed grating, the bars of which shall not be more than three-eighths of an inch apart.

(e) The inner walls shall be covered with hard, smooth impervious material, to the height of four feet at the least; and such covering shall be always kept in good order and repair.

(f) There shall be provided one or more inlet valves for air, adequate for supplying a sufficient quantity of fresh air from the outside of the chamber for the persons employed and working therein, and so constructed as not to allow the atmosphere of the chamber to escape thereby; and such valve or valves shall be always kept in good working order and repair.

(g) There shall be provided a shaft to lead from the upper part of a close chamber to a furnace, and such shaft shall be so constructed that any gas or air drawn through the shaft shall be consumed in the furnace fire.

(h) There shall be no room or loft over any such chamber, other than a room used solely for the purpose of the business; and such room shall be provided with separate means of access from without, and shall not communicate directly or indirectly with any close chamber.

15. Every Cat Gut Maker shall provide, or cause to be provided, upon the premises on which his business is carried on machinery or appliances for effectually drawing the atmosphere from a close chamber or chambers, and from every room or place in which any offensive vapour or gas may be evolved, through a shaft and into a furnace fire.

16. He shall cause all needful works and repairs to the premises to be forthwith done and executed as and when the same shall become requisite, and shall not allow any alteration whatsoever to be made in respect of the structure of the premises without the consent of the Board.

17. Every person who shall not comply with any of the foregoing Bye-Laws relating to the structure of the premises shall be guilty of an offence, and shall be liable, for every such offence, to a penalty of Five pounds, and in the case of a continuing offence, to a penalty of One pound for every day during which the offence may be continued after the conviction for the first offence.

Bye-Law for Regulating the Mode of Application for Sanction to New Establishment of the Business.

18. Every person who may apply to the Board for their sanction to establish anew the Business of a Cat Gut Maker shall furnish with the application a plan of the premises and sections of the buildings in which it is proposed to carry on such business, such plans and sections being drawn to a scale of a quarter of an inch to the foot, and showing the provision made, or proposed to be made, for the drainage, lighting, ventilation, and water supply of such premises, and for the construction of close chambers thereon, and shall also furnish a key plan of the locality, showing the buildings and streets within one hundred yards of the premises, drawn to a scale of five feet to the mile.

(185) *The Boiling of Tripe.*

The nuisance (and its remedy) from the boiling of tripe is sufficiently detailed in the following byelaws in force in the Metropolis:—

LONDON COUNTY COUNCIL.

THE SLAUGHTERHOUSES, &c. (METROPOLIS) ACT, 1874, 37 & 38 *Vic.*, c. 67.

BYE-LAWS for the regulation of the conduct of the business of a Tripe Boiler, the structure of the premises on which such business is carried on, and the mode in which application is to be made for sanction to establish such business anew, within the limits of the Metropolis (except the City of London and the liberties thereof.)

In pursuance of the above Act by which the Metropolitan Board of Works[1] is constituted the Local Authority for the Metropolis as defined in the same Act (except the City of London and the liberties thereof), the said Metropolitan Board of Works[1] (for the purpose of these Bye-Laws called the "Board") doth hereby make the following Bye-Laws :—

Bye-Laws for Regulating the Conduct of the Business.

1. Every Tripe Boiler shall cause the premises on which his business is carried on to be constantly provided with an adequate supply of water, which shall be received and stored in cisterns, or other suitable receptacles, properly constructed, and he shall cause such premises at all times to be well and thoroughly ventilated by suitable openings, windows, Louvre boards, or otherwise. He shall cause every part of such premises to be thoroughly washed from time to time, as often as may be necessary, and to be kept at all times thoroughly clean.

2. Every Tripe Boiler shall cause every inner wall of the premises on which his business is carried on to be kept at all times thoroughly clean and in good order and repair. He shall cause every such wall to be thoroughly washed with hot lime-wash in the first week of each of the months of March, June, September, and December.

3. Every Tripe Boiler shall provide a sufficient number of tubs, boxes, or vessels, constructed of galvanized iron or other non-absorbent material, and furnished with tight and close-fitting covers, for the purpose of receiving and conveying away all manure, garbage, offal, and filth. He shall, from time to time, as often as occasion may require, cause such manure, garbage, offal, and filth to be placed in such tubs, boxes, and vessels, and to be removed from his premises without delay.

4. Every Tripe Boiler shall cause every boiler or other vessel from which any offensive or noxious vapour or gas may be evolved in the operation of boiling, or otherwise, to be properly covered, and in all other respects to be so constructed and used as to cause all such vapour or gas to be effectually conveyed into, or through, a furnace fire, or otherwise to be prevented from escaping into the external atmosphere.

5. Every Tripe Boiler shall cause every tub, box, vessel, boiler, or receptacle provided or used upon, or in connection with, the premises on which his business may be carried on, to be kept at all times thoroughly clean, so as to prevent any offensive smell.

6. Every Tripe Boiler shall cause all offal, or other materials used in his business, when delivered on to the premises across a public footpath, to be conveyed in vessels properly covered and constructed.

7. Every Tripe Boiler shall remove, or cause to be removed, from the premises on which his business is carried on, every bone, fat, offal, garbage, or other similar article before it has become putrid or offensive.

8. Every Tripe Boiler shall afford access to every part of the premises on which his business is carried on, to every Member and Officer of the Board authorised in writing under the hand of the Clerk of the said Board, at any reasonable time during the hours within which such business may be carried on.

9. Every person offending against any of the foregoing Bye-laws shall be liable for every such offence, to a penalty of Five pounds, and in the case of a continuing

[1] To be now read "London County Council."

offence, to a penalty of One pound for every day during which the offence may be continued after the conviction for the first offence.

10. Every Court of Summary Jurisdiction, as defined in the Slaughterhouses, &c., (Metropolis) Act, 1874, may, as a penalty for the breach of any of the foregoing Bye-laws, by summary Order, suspend or deprive any person altogether of the right of carrying on the business of a Tripe Boiler.

Bye-law for Regulating Mode of Application for Sanction to new Establishment of Business.

11. Every person who may apply to the Board for their sanction to establish anew the business of a Tripe Boiler, shall furnish with his application a plan of the premises and sections of the building in which it is proposed to carry on such business, such plan and sections being drawn to a scale of a quarter of an inch to the foot, and showing the provision made, or proposed to be made, for the drainage, lighting, ventilation, and water supply of such premises; he shall at the same time furnish the Board with a key plan of the locality, showing the buildings adjacent to the premises, such plan being drawn to a scale of five feet to the mile.

Bye-laws for Regulating the Structure of the Premises.

12. Every Tripe Boiler shall cause the premises on which his business is carried on to be well paved with asphalte, Yorkshire flag-stone, Stourbridge paving bricks, closely set in cement upon a bottom of four inches of good concrete, or with other suitable material, and to be laid with a proper slope and channel towards the gully, and to be effectually drained by an adequate drain of glazed pipes communicating with the public sewer, and properly ventilated. He shall cause such gully to be properly trapped, and to be covered with a grating, the bars of which shall not be more than three-eighths of an inch apart.

13. Every Tripe Boiler shall cause all works and repairs to the premises to be forthwith done and executed as and when required by the Board; and shall not make or allow to be made any alteration whatsoever in respect of the structure of the premises, without the consent of the Board.

(186) *Slaughterhouses.*

It is hoped the time is not far distant when private slaughterhouses in large population centres will be abolished. The public health cannot be protected, nor the sale of diseased animals controlled, except in abbatoirs.

Nuisances arise in private slaughterhouses from the keeping of the animals previous to killing them, from the operations themselves, and from the garbage and refuse.

The place where cattle are kept and fed for several days before killing is technically called a "lair," but where they are temporarily detained before slaughter is called "a pound;" but in small businesses the one shed or place serves for both lair and pound.

The neighbours of slaughtering places frequently—and with reason—complain of the bleating of sheep and the lowing of cattle. There may be also a good deal of odour from a number of animals being crowded together. Although noise, *per se*, does not come

within the scope of the Public Health and Sanitary Acts, it is at all events an annoyance, and aggravates other causes of complaint.

In slaughtering, the oxen in this country are usually poleaxed; in a few places they are shot, the gun being loaded with a marble (a bullet breaking up the tissues too much): through the hole in the animal's skull, thus produced, a cane is thrust down the spinal marrow. Death is not so rapid as is generally thought. The author has seen bullocks struggle for several minutes. Sheep have their throats cut; pigs are killed by cutting into the great vessels of the neck. The squeals, or almost human shrieks, of the latter are peculiarly distressing, and, from the high pitch of the sounds, are heard a long distance. Some butchers stun the pig first in order to avoid the noise.

The butcher in one way or another is able to dispose of almost all *débris* arising from the operation of slaughtering. The blood is used as a food for man or pigs, or it is defibrinated and utilised in Turkey-red dyeing, or it is sent to the manufacturer of blood albumen. The skins, hoofs, horns, all find buyers. Parts of the intestines and internal organs, not readily saleable, are converted into dogs' and cats' meat; the contents of the intestines are used as manure.

Nevertheless, unless the slaughterhouse itself is constructed with proper tanks or receptacles for the blood, unless it is properly paved, lighted, and drained, and supplied with ample water supply, and above all if the greatest cleanliness be not observed, it is likely to become, more especially in summer time, an intolerable nuisance. Probably blood putrefaction is liable to produce septic diseases and puerperal fever; in medical literature general statements are to be found giving some support to this theory. That putrefying blood contains poisonous elements is capable of proof: witness the practice of many uncivilized tribes who smear their weapons with blood, such weapons acquiring specially dangerous qualities. Hence, pits used for the receipt of blood, or vessels generally which have been used in a slaughterhouse, should not alone be thoroughly cleansed, but also disinfected daily.

The methods to be adopted and recommended in the conservation and establishment of slaughterhouses cannot be better elucidated than by a perusal of the following Metropolitan Byelaws under the Metropolitan Slaughterhouse Act:—

LONDON COUNTY COUNCIL.

37 *and* 38 *Vict.*, c. 67.

Bye-laws for Slaughterhouses in the County of London.

In pursuance of the Slaughterhouses, &c. (Metropolis), Act, 1874, and of the Local Government Act, 1888, the London County Council hereby make the following Bye-laws for regulating—

(*a*) The conduct of the business of a slaughterer of cattle ;
(*b*) The structure of the premises in which such business is being carried on ; and
(*c*) The mode in which application is to be made for sanction to establish such business anew within the County of London (except the City of London and the Liberties thereof), that is to say—

Bye-laws for Regulating the Conduct of the Business of a Slaughterer of Cattle in the County of London.

1. Every occupier of a slaughterhouse—

(*a*) Shall cause all animals intended for slaughter to be kept upon the premises only in pounds, pens, or lairs.

(*b*) He shall not keep in a slaughterhouse, or in such pounds, pens, or lairs any animals not intended for slaughter, or any animals the flesh of which would be unfit for use as human food.

(*c*) He shall not keep in such pounds, pens, or lairs a greater number of animals than is herein provided, that is to say—

1. In the case of cattle, one animal to every twenty-four square feet of floor space therein.
2. In the case of calves, one animal to every eight square feet of floor space therein.
3. In the case of sheep, lambs and pigs, one animal to every six square feet of floor space therein.

(*d*) He shall not keep therein any animals for a longer period than may be necessary for the purpose of preparing such animals for slaughter.

(*e*) He shall provide such animals with a sufficient quantity of wholesome water and food.

2. Every occupier of a Slaughterhouse—

(*a*) Shall slaughter all animals in the slaughterhouse, and shall not slaughter or permit to be slaughtered any animal in any pound, pen, or lair, or in any part of the premises other than the slaughterhouse.

(*b*) He shall, in slaughtering animals use such instruments and appliances, and adopt such method of slaughtering, and otherwise take such precautions, as may be requisite to prevent unnecessary suffering to any animal.

(*c*) He shall not slaughter or permit to be slaughtered any animal within public view, or within the view of other animals.

(*d*) He shall provide sufficient vessels or receptacles, properly constructed of galvanised iron or other non-absorbent material, and furnished with close fitting covers ; and shall cause all blood from any animal slaughtered to be caught and placed in such vessels or receptacles.

(*e*) He shall, upon the completion of any slaughtering, cause all manure, garbage, filth, or any refuse residues from the animals slaughtered, to be forthwith placed in such vessels or receptacles.

(*f*) He shall cause such vessels or receptacles to be kept closed while containing any of the aforesaid substances.

(*g*) He shall cause all such substances to be removed and conveyed from the premises in such closed receptacles.

(*h*) He shall cause the fat of any animal slaughtered to be kept freely exposed to the air while upon the premises.

(*i*) He shall cause all blood, manure, garbage, filth, or any refuse residues from animals slaughtered, and all hides, skin, fat, and offal therefrom, to be removed from the premises within twenty-four hours of the completion of

slaughtering, in such manner and by such means as will not cause nuisance either at the premises or in the public streets.

(*k*) He shall, as far as is reasonably practicable, prevent any blood, manure, garbage, filth, or any refuse residues from animals slaughtered entering any drain or sewer, or any inlet to any drain or sewer.

3. Every occupier of a Slaughterhouse—

(*a*) Shall cause every part of the floor of such slaughterhouse, and every other internal part of such slaughterhouse, and also the fittings thereof, upon which any blood, or refuse, or filth may have been spilled, splashed, or deposited, to be thoroughly washed and cleansed within three hours after the completion of any slaughtering.

(*b*) He shall cause every part of such floor and all internal walls and fittings within six feet of such floor to be at all times kept in good order and repair, so as to prevent the absorption therein of any blood, or liquid refuse, or filth.

(*c*) He shall not permit the surfaces of the walls and fittings within six feet of the floor to be covered with cementwash, limewash, or other like substance.

(*d*) He shall cause all utensils, receptacles, and appliances used in such business to be kept, when not in actual use, in a thoroughly clean condition.

(*e*) He shall cause all internal walls and fittings of such slaughterhouse not within six feet of the ground, and the internal walls and fittings of any pound, pen, or lair, to be thoroughly limewashed with hot limewash at least four times in every year: that is to say, between the 1st and the 10th days of the months of March, June, September, and December respectively.

(*f*) He shall cause all dung and offensive litter to be swept up and removed from every pound, pen, or lair at least once a day, and such place to be thoroughly cleansed as often as may be necessary to keep the same in a clean condition.

4. Every occupier of a Slaughterhouse—

(*a*) Shall cause the means of ventilation provided thereto, and to any pound, pen, or lair to be kept in proper order and efficient action so that at all times such slaughterhouse, pound, pen or lair shall be effectually ventilated by direct communication with the external air.

(*b*) He shall cause the means of drainage provided in or upon his premises to be kept at all times in proper order.

(*c*) He shall cause the means of water supply provided upon his premises to be kept in proper order, and shall at all times provide a sufficient supply of water for the proper cleansing of his slaughterhouse, pounds, pens, or lairs, and of the vessels and receptacles therein.

5. Every occupier of a Slaughterhouse—

(*a*) Shall allow the slaughterhouse to be used for no other purpose than the slaughtering and dressing of animals the flesh of which is fit for, and is intended to be sold as, human food.

(*b*) He shall allow no person other than himself and his servants to slaughter animals or dress the carcases thereof upon his premises, unless he is authorised to do so by the Council in writing.

6. Every occupier of a Slaughterhouse shall at all times employ such means and adopt such precautions as may be necessary for preventing nuisance arising upon his premises.

7. Every occupier of a Slaughterhouse shall at all reasonable times afford free access to every part of his premises to the Inspectors and other persons authorised by the Council in writing to inspect slaughterhouses, and he shall enable such Inspectors or other persons to examine the premises without obstruction or unnecessary delay.

8. Every person breaking any of the foregoing Bye-laws shall be liable for every offence to a penalty of not exceeding Five pounds; and in the case of a continuing offence to a penalty of One pound for every day during which the offence may be continued after conviction for the first offence.

9. In pursuance of the provision in that behalf contained in Section 4 of the Slaughterhouses, &c., Metropolis Act, 1874, power is hereby given to every Court of Summary Jurisdiction, by summary order, to suspend or deprive any person altogether

of the right of carrying on the business of a Slaughterer of Cattle, as a penalty for breaking any of the foregoing Bye-laws.

Bye-laws for Regulating the Structure of the Premises upon which the Business of a Slaughterer of Cattle is being carried on in the County of London.

10. Every such premises shall include a Slaughterhouse and one or more pounds, pens, or lairs, and—

(*a*) Such slaughterhouse shall have a floor space of at least one hundred square feet, and the walls thereof to a height of six feet from the ground shall be substantially constructed of brick, stone, iron or concrete; and such slaughterhouse shall be covered with a properly constructed roof.

(*b*) Such pounds, pens, or lairs shall be separated from such slaughterhouse by means of close partitions to a height of at least five feet in the case of cattle, and at least three feet in the case of sheep, lambs and pigs, and all doors in such partitions shall be closely boarded.

(*c*) Such premises shall have an approach to the slaughterhouse which shall be throughout of a width of at least three feet six inches, and such approach shall not be up or down steps, or over slopes having a steeper gradient than one foot in four feet; provided that where sheep, lambs and pigs only are killed, the width of the approach shall be at least two feet nine inches throughout.

11. Every Slaughterhouse and pound, pen, or lair upon such premises—

(*a*) Shall be well and sufficiently lighted and ventilated by louvred openings in the walls and roofs, or by other approved openings, windows, or lights.

(*b*) Shall be well paved with granite, cement, concrete, or with other approved hard and impervious material set with cement properly bedded on concrete; and such paving shall have a proper slope towards a gully-hole; and such gully-hole shall communicate by an adequate drain of glazed stoneware pipes with the public sewer, and be trapped by an appropriate fixed trap, and be covered with a fixed grating, the bars of which shall be not more than ⅜ inch apart.

(*c*) Shall be provided with means for an adequate supply of water; and where there is not a constant water supply, with a slate, metal, or metallic-lined tank, the bottom of which shall be not less than six feet from the floor; and such tank shall be properly covered, and an adequate water trough shall be in every pound, pen, or lair.

12. Every Slaughterhouse shall have the inner walls, doors, and woodwork covered with hard, smooth, and impervious material to a height of at least six feet from the floor.

13. A Slaughterhouse shall not have any rooms or lofts thereover, and a slaughterhouse, pound, pen, or lair—

(*a*) Shall not have any openings therefrom directly into any building used as a dwelling.

(*b*) Shall not contain any water-closet, privy, urinal, or stable; and a water-closet, privy, urinal or stable shall not be in direct communication with, or ventilate into, any slaughterhouse.

14. Every person who shall not comply with any of the foregoing Bye-laws relating to the structure of the premises shall be guilty of an offence, and shall be liable, for every such offence, to a penalty of not exceeding Five pounds, and, in the case of a continuing offence, to a penalty of One pound for every day during which the offence may be continued after the conviction for the first offence. Provided always, that the foregoing Bye-laws for regulating the structure of the premises shall not, until after the expiration of six months from the date of the confirmation of the Bye-laws, be deemed to apply to any premises where at such date the business of a Slaughterer of Cattle may be carried on; and further provided, that a requirement of such Bye-laws for regulating the structure of the premises shall not be deemed to apply to any premises in respect of which the London County Council shall have, by endorsement in writing on the back of any current license to use such premises as a slaughterhouse, exempted such premises from such requirement.

Bye-laws for Regulating the Mode in which Application is to be made for Sanction to Establish Anew the Business of a Slaughterer of Cattle in the County of London.

15. Every person applying for such sanction—
(*a*) Shall furnish, in the form prescribed by the Council, the particulars specified in such form, as to the situation of the premises, and as to the arrangement and construction of the buildings in which such business is proposed to be established.
(*b*) He shall also furnish a plan of such premises and sections of the buildings, drawn to a scale of one-eighth of an inch to one foot, showing the buildings proposed to be used as slaughterhouse, pounds, pens or lairs, their construction, the provision for drainage, and the means proposed for lighting and ventilation.
(*c*) He shall also furnish a key plan of the locality, showing the site, and all buildings, dwellings, streets and places within 250 yards of such site, and such key plan shall be drawn to a scale of five feet to one mile.

Repeal.

In further pursuance of the Acts aforesaid, the said London County Council hereby repeal the Bye-laws regulating the conduct of the business of a Slaughterer of Cattle, the structure of the premises on which such business is being carried on, and the mode in which application is to be made for sanction to establish such business anew, made on the seventh day of May, 1875, by the Metropolitan Board of Works, and confirmed by the Local Government Board on the twenty-seventh day of May, 1875.

(187) *Knackers' Yards.*

The same principles previously detailed as to the slaughtering of cattle are also applicable to knackers' yards, or, as they are otherwise called, "knackeries." But there is this difference between the two: the slaughterer of cattle is presumed to kill healthy animals, the knacker those that are old or diseased; added to which, the knacker usually unites with his business the offensive operation of boiling a large quantity of the flesh and offal for cats' meat.

A well-managed knacker's yard in close vicinity to houses must itself be considered a nuisance, provided there is much business done. It cannot but be detrimental to health to have a collection of diseased material—such as horses suffering from glanders and farcy or tuberculosis, or animals with suppurating sores—within a short distance of dwelling-houses; and it may be taken as a general advice to a sanitary authority to oppose the establishment of any new business of the kind within a quarter of a mile of any collection of inhabited houses.

The following are the regulations in force in the metropolis as to knackeries:—

LONDON COUNTY COUNCIL.

THE SLAUGHTERHOUSES, &C. (METROPOLIS), ACT, 1874, 37 *and* 38 *Vic.*, c. 67.

BYE-LAWS for regulating the conduct of the business of a Knacker, *i.e.*, a person whose business it is to slaughter any horse, ass, or mule, or any cattle, sheep, goat, or swine, which is not killed for the purpose of its flesh being used as butcher's meat, and the structure of the premises on which such business is being carried on, within the limits of the Metropolis (except the City of London and the liberties thereof).

In pursuance of the above Act, by which the Metropolitan Board of Works[1] is constituted the Local Authority for the Metropolis, as defined in the said Act (except the City of London and the liberties thereof), the said Metropolitan Board of Works[1] (for the purposes of these Bye-laws called the "Board") doth hereby make the following Bye-Laws. Throughout and for the purposes of these Bye-Laws "the premises" shall mean and include the slaughterhouse, and all the premises used for and forming part of the business of a Knacker as defined by the Act, and "slaughter-house" shall mean the portion of the premises used for the slaughtering and dressing of the animals above-mentioned, and "occupier" shall mean the occupier of premises where the business of a Knacker is carried on, and "contagious or infectious disease" shall include Cattle Plague, Pleuro-pneumonia, Foot and Mouth Disease, Sheep Pox, Sheep Scab, Glanders, and Farcy.

As to the Conduct of the Business of a Knacker.

1. The occupier shall not slaughter, or permit to be slaughtered, on the premises any animal that is intended or fit to be used for human food, nor keep or permit to be kept, any fowl, pig, or other animal used for human food in or about the premises nor any dog thereon.

2. The occupier shall not allow any room situated over a slaughterhouse to be inhabited under any pretext whatsoever.

3. The occupier shall not allow the slaughterhouse to be used for any purpose other than that for which it is licensed, nor any slaughtering to be conducted within public view.

4. The occupier shall keep the inner walls of the slaughterhouse always thoroughly clean and in good order and repair, and shall cause the internal surface of the roof and upper portions of the walls to be thoroughly washed with quicklime, at least once in every three months, and he shall also keep every yard and other part of the premises clear.

5. The occupier shall provide and keep a sufficient number of tubs, boxes, or vessels, formed out of proper non-absorbent materials, with tight and close-fitting covers thereto, for the purpose of receiving and conveying away all manure, garbage, offal, and filth; and shall, in all cases, immediately after the slaughtering is completed, cause all such manure, garbage, offal, and filth to be placed in such tubs, boxes, and vessels; and shall cause all the blood arising from the slaughtering to be put into separate tubs or vessels formed out of the like materials as above with close-fitting covers; and every such tub, box, and vessel, together with their contents, to be removed from the premises within twenty-four hours.

6. The occupier shall keep every covered and other receptacle used in the slaughterhouse at all times thoroughly cleansed and purified, so as to prevent any offensive smell.

7. The occupier shall cause every boiler and vessel from which any offensive or noxious vapour or gas may be evolved in the operation of boiling or otherwise, to be covered over and constructed so that every such gas and vapour shall be effectually conveyed into or through a furnace-fire, or shall be otherwise prevented from escaping into the external atmosphere.

8. The occupier shall cause every hide and skin to be removed from the premises

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[1] Read now London County Council.

within forty-eight hours after slaughtering, and every hide of a glandered or farcied horse, mule, or ass to be disinfected before removal.

9. The occupier shall remove, or cause to be removed from the premises, every carcase, bone, hide, skin, and all meat, fat, offal, blood, garbage, and other articles before the same have become putrid or offensive.

10. In case of any horse or other such animal as above-mentioned that is affected with either an infectious or contagious disease being brought to the premises of a Knacker, he shall not suffer it to be removed, but shall forthwith give information thereof to the Board, and to the Cattle Inspector for the District, appointed under the Contagious Diseases (Animals) Act, 1869, with all details in his knowledge as to the name and address of the person bringing the horse or animal, and the owner and the place from which the same was brought, and the time when it was brought.

11. The occupier shall allow every Member of the Board, in addition to all other persons lawfully entitled to admission, to have free access to the premises during the times of slaughter, and at all reasonable hours.

12. The occupier, if he neglect or omit to observe or perform or shall in any way break any one of the above Bye-Laws, shall be subject to a penalty of the sum of £3, and in the case of a continuing offence the sum of £1 for every day during which such offence is continued after a conviction for the first offence.

13. Every court of Summary Jurisdiction, as defined by the Slaughterhouses, &c. (Metropolis), Act, 1874, having jurisdiction to hear and decide complaints of the breach of the above Bye-Laws, may, by Summary Order, suspend or deprive any Knacker altogether of the right of carrying on any such business, as a penalty for the breach of any one of the above Bye-Laws.

As to the Structure of the Premises upon which the Business of a Knacker is carried on.

14. The occupier shall cause the slaughterhouse to be provided with an adequate tank or other proper receptacle for water and water supply, and so placed that the bottom thereof shall not be less than six feet above the level of the floor; and shall cause the slaughterhouse to be well and thoroughly ventilated.

15. The occupier shall cause the slaughterhouse to be well paved with asphalte, or flag stone, or proper paving bricks, set in cement, to be laid with proper slope and channel towards a gully, and to be effectually drained by an adequate drain of glazed pipes or in other sufficient manner communicating with the public sewer, and the gully to be trapped by an appropriate trap, and to be covered with a grating, the bars of which shall not be more than three-eighths of an inch apart.

16. The occupier shall cause every inner wall of the slaughterhouse to be covered with hard, smooth, impervious material, to the height of four feet at the least, and to be always kept in good order and repair.

17. The occupier shall cause all needful works and repairs to the premises to be forthwith done and executed as and when the same shall become requisite; and shall not allow any alteration whatsoever to be made in respect of the paving, drainage, ventilation, or water supply to or in the premises which have been licensed, without the consent of this Board.

18. The occupier, if he neglect or omit to observe or perform, or shall in any way break any one of the Bye-Laws, as to the structure of the premises, shall be subject to a penalty of the sum of £5, and in the case of a continuing offence, the sum of £1 for every day during which such offence is continued after a conviction for the first offence.

CHAPTER XXI.

EFFLUVIUM NUISANCES CONNECTED WITH TRADES.

(188) *Classification of Effluvium Nuisances.*[1]

THE most offensive nuisances, says Ballard, are those which are given off from trade processes in which the materials used consist mainly of animal matters, or which contain elements of animal origin. The most disgusting of all are the effluvia from the process of gut-scraping and the preparation of sausage skins and catgut, the preparation of artificial manures from "scutch" (refuse matters in the manufacture of glue), the manufacture of some other kinds of artificial manures, and the melting of some kinds of fat. Manufacturing businesses which deal with vegetable substances are often very offensive, but only rarely can be said to give rise to distinct effluvia.

Among the most offensive are those in which the effluvia are thrown off during the heating of vegetable oils, as, for example, during the boiling of linseed oil, the manufacture of palmitic acid from cotton oil foots, from palm oil, the manufacture of some kinds of varnish, the drying of fabrics coated with such varnishes, and the burning of painted articles, such as disused meat tins. Among the trades which deal with neither animal nor vegetable substances the most offensive effluvia are produced from the manufacture of ammonium sulphate or ammonium chloride, and some other processes or manufacture in which the copious evolution of SH_2 occurs, and from gas making and the distillation of tar.

[1] In this chapter much use is made of Dr. Ballard's exhaustive report on effluvium nuisances in Supplemental Reports of Local Government Board, 1876, 1877.

Dr. Ballard classifies effluvium nuisances as follows:—

(1) The keeping of animals.

(2) The slaughtering of animals [see *ante*, chap. xx. p. 263].

(3) Other branches of industry, in which animal matters or substances of animal origin are principally dealt with.

(4) Branches of industry in which vegetable matters are principally dealt with.

(5) Branches of industry in which mineral substances are principally dealt with.

(6) Branches of mixed origin in which mineral, vegetable, and animal substances are dealt with.

(189) *Pig-keeping.*

It is specially stated by the Public Health Act that pigs must not be kept in towns so as to be a nuisance (sec. 47). The sources of offence are chiefly:—The "wash," or other offensive food; the excreta.

It seems to be a popular prejudice that no substance is too nasty or repulsive to throw to pigs, hence the horribly fœtid putrefying liquid, the waste of the kitchen known as "wash," now so largely used. As however with other animals, cleanliness of food tends to health; the pig thrives most and produces the healthiest flesh when nourished on cleanly, wholesome food. The species of feeding most to be condemned is however that practised by many butchers, viz. giving to the pig the uncooked *débris* and blood of the slaughter-house; it is in this way that pork is so liable to be contaminated with tubercle and parasites.

The excreta of the pig are peculiarly offensive; there is no more penetrating stink than that evolved in cleaning out a pigstye. If pigs are to be kept at all in towns it must be under stringent regulations, one of which may well be a thorough daily cleansing of the stye and removal of the manure in proper closed receptacles either at night or early in the morning. Dr. Ballard points out that all the pachydermata roll in the mud in order to get rid of the irritating effete epidermis. The mud cakes on the skin and when dry falls off, carrying with it the cutaneous *débris.* If a pig is well scrubbed with water, he does not wallow in his own manure, so that in this way the animals themselves may be kept in a fairly cleanly state.

(190) *Bacon Curing.*

The singeing of the hair of the pig, which is one of the first operations, may cause an unpleasant smell, especially if this is done in the open, and not underneath a hood adapted to lead the fumes into a shaft. Much of the American pork is converted into bacon. It is first soaked in water to remove salt; it is then rapidly dried in a closed chamber by the heat of a central coke fire; the windows of the chamber are then opened and the bacon exposed to a current of fresh air. In one case quoted by Dr. Ballard, observed by Dr. Spear, the process was conducted in South Shields in an unventilated cellar beneath an inhabited room, the inhabitants of which complained bitterly of the smell of the steam which entered their room through the loosely-boarded floor. In Liverpool, nuisance has also been caused from this business by the discharge of warm water into the drains from the washing of the pork, the effluvia bursting up through the gullies.

(191) *Nuisance from Stables* (*Horse Keeping*).

The sources of nuisance are—

(1) Soakage of urine into the ground from imperfect paving.

(2) Emanations from the dung.

(3) Impurity of the atmosphere due to cutaneous and lung exhalations of the animals kept therein.

A country stable, a reasonable distance from human habitation, is not likely to be complained of, although against the interests of the horses it may be ill-ventilated, ill-kept, and the manure only dealt with at long intervals. The keeping of stables and mews in order is a daily care to the sanitary authorities of large towns, the more especially when the floor above is used as a habitation.

In the metropolis there are many thousands of persons living over stables and constantly breathing an atmosphere impregnated with ammonia. There are no reliable statistics on the subject, but such conditions cannot be conducive to high vigorous health. Stables should of course have a perfectly impervious floor, and the drains should be well laid and of good materials. There should also be no difficulty in making the floors of the living rooms above stables of impervious material, and I think a sanitary authority would be justified on complaint of nuisance owing to stable

emanations rising through a pervious floor, in giving notice to remedy the nuisance.

I have found in several instances that the drinking water stored in a cistern within stables has been so impregnated with ammonia as to actually smell and taste of that substance. Hence it is important to notice the position of the cistern, and to insist that it shall have a proper cover.

The nuisance from dung is mainly in its removal, when it has been previously stored in heaps. The heap is liable to ferment, and then when disturbed gives off watery vapour charged with a peculiarly strong-smelling ammonia. The method adopted in some large stables is to each morning put the dung direct into a cart and thus avoid making a heap at all. In any case dung-pits are unmitigated nuisances in towns and should be discountenanced. A cage of iron bars at or near the door of each stable is about the neatest and most unobjectionable form of storage receptacle, the free admission of air preventing fermentation. Ammoniacal emanations, and consequently loss of a valuable fertilizing agent, may be controlled by wetting the manure with dilute sulphuric acid; its commercial value in this way is certainly increased.

(192) *Cow Keeping.—Dairies.*

As in the case of keeping horses so in the case of cow keeping, the question of nuisance mainly arises in towns.

The sources of nuisance from the keeping of cows are—

(1) Impurity of the atmosphere in and around the shed.

(2) Emanations from the dung of the animals.

(3) The storing of grains.

Cow-sheds are seldom adequately ventilated, for the cow-keeper knows by experience that unless he keeps the shed warm the cows do not secrete so much milk. To transform the cow into a milk-producing machine the animal must be kept in-doors, fed highly, and kept at a temperature of from 65° to 75°. Hence the health officer will find all proposals to sweeten the atmosphere by free ventilation looked at with much disfavour. The cow passes daily an immense quantity of semiliquid manure and a large quantity of urine; there is also atmospheric contamination from the lungs, and it is to be remembered that in addition to carbon dioxide, the

cow passes from the intestine much marsh gas. It is of the utmost importance that the floor be properly paved with impervious material and that the drainage be perfect; there must also be an abundant supply of water; this is best stored in a capacious tank, to which a long hose may be attached. The manure from a large cowhouse should be removed at least once a day, and the floor washed down morning and evening; in no other way can the air be kept even moderately free from odour.

A third source of nuisance arises from the grains so generally in towns used as a food. The grains are stored up in a wet state, and unless they are freed from the liquid, acetous fermentation proceeds and a penetrating sour smell is very evident. It is best to store the grains in two receptacles, and directly the one is empty it should be well washed and scrubbed with hot water. The reason for this precaution is, that unless the receptacles themselves are regularly washed, they become impregnated with the acetous liquor, and, quite irrespective of the grains, are a source of nuisance.

In model cowsheds the racks and partitions are made of iron, which is a great improvement on wood. The walls themselves are preferably lined with glazed tiles. Any living room over a cowshed, the atmosphere of which is in direct communication with it, should most decidedly be condemned as unfit for human habitation.

The general regulations in force as to cow-keeping are as follows:—

(193) *Dairies', Cowsheds', and Milk Shops' Order.*

LONDON COUNTY COUNCIL.

41 *and* 42 *Vic.*, Ch. 74, *and* 49 *and* 50 *Vic.*, Ch. 32.

REGULATIONS AS TO DAIRIES, COWSHEDS, AND MILKSHOPS.

THE DAIRIES, COWSHEDS, AND MILKSHOPS ORDER OF 1885, AS AMENDED BY THE DAIRIES, COWSHEDS, AND MILKSHOPS AMENDING ORDER OF 1886, PROVIDES AS FOLLOWS:—

Registration of Dairymen and others.

Section 6.—(1.) It shall not be lawful for any person to carry on in the District of any Local Authority the trade of cowkeeper, dairyman, or purveyor of milk unless he is registered as such therein in accordance with this Article.

(2.) Every Local Authority shall keep a Register of persons from time to time carrying on in their District the trade of cowkeepers, dairymen, or purveyors of milk, and shall from time to time revise and correct the Registers.

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(3.) The Local Authority shall register every such person, but the fact of such registration shall not be deemed to authorise such person to occupy as a dairy or cowshed any particular building, or in any way preclude any proceedings being taken against such person for non-compliance with or infringement of any of the provisions of this Order or any Regulation made thereunder.

(4.) The Local Authority shall from time to time give public notice by advertisement in a newspaper circulating in their District, and, if they think fit, by placards, hand-bills, or otherwise, of registration being required, and of the mode of registration.

(5.) A person who carries on the trade of cowkeeper or dairyman for the purpose only of making and selling butter or cheese or both, and who does not carry on the trade of purveyor of milk, shall not, for the purposes of registration, be deemed to be a person carrying on the trade of cowkeeper or dairyman, and need not be registered.

(6.) A person who sells milk of his own cows in small quantities to his workmen or neighbours, for their accommodation, shall not, for the purposes of registration, be deemed, by reason only of such selling, to be a person carrying on the trade of cowkeeper, dairyman, or purveyor of milk, and need not, by reason thereof, be registered.

Construction and Water Supply of New Dairies and Cowsheds.

Section 7.—(1.) It shall not be lawful for any person following the trade of cowkeeper or dairyman to begin to occupy as a dairy or cowshed any building not so occupied at the commencement of this Order, unless and until he first makes provision, to the reasonable satisfaction of the Local Authority, for the lighting and the ventilation, including air-space, and the cleansing, drainage, and water supply of the same, while occupied as a dairy or cowshed.

(2.) It shall not be lawful for any such person to begin so to occupy any such building without first giving one month's notice in writing to the Local Authority of his intention so to do.

Sanitary State of all Dairies and Cowsheds.

Section 8. It shall not be lawful for any person following the trade of cowkeeper or dairyman to occupy as a dairy or cowshed any building, whether so occupied at the commencement of this Order or not, if, and as long as, the lighting and the ventilation, including air-space, and the cleansing, drainage, and water supply thereof, are not such as are necessary or proper—

(*a.*) for the health and good condition of the cattle therein; and

(*b.*) for the cleanliness of milk-vessels used therein for containing milk for sale; and

(*c.*) for the protection of the milk therein against infection or contamination.

Contamination of Milk.

Section 9. It shall not be lawful for any person following the trade of cowkeeper or dairyman or purveyor of milk, or being the occupier of a milk-store or milk-shop—

(*a.*) To allow any person suffering from a dangerous infectious disorder, or having recently been in contact with a person so suffering, to milk cows or to handle vessels used for containing milk for sale, or in any way to take part or assist in the conduct of the trade or business of the cowkeeper or dairyman, purveyor of milk or occupier of a milk-store or milk-shop, so far as regards the production, distribution, or storage of milk; or

(*b.*) If himself so suffering or having recently been in contact as aforesaid, to milk cows, or handle vessels used for containing milk for sale, or in any way to take part in the conduct of his trade or business as far as regards the production, distribution, or storage of milk—

until in each case all danger therefrom of the communication of infection to the milk or of its contamination has ceased.

Section 10. It shall not be lawful for any person following the trade of cowkeeper or dairyman or purveyor of milk, or being the occupier of a milk-store or milk-shop after the receipt of notice of not less than one month from the Local Authority, calling attention to the provisions of this Article, to permit any water-closet, earth-closet, privy, cesspool, or urinal to be within, communicate directly with, or ventilate into, any dairy or any room used as a milk-store or milk-shop.

Section 11. It shall not be lawful for any person following the trade of cowkeeper or dairyman or purveyor of milk, or being the occupier of a milk-store or milkshop to use a milk-store or milk-shop in his occupation, or permit the same to be used as a sleeping apartment, or for any purpose incompatible with the proper preservation of the cleanliness of the milk-store or milkshop, and of the milk-vessels and milk therein, or in any manner likely to cause contamination of the milk therein.

Section 12. It shall not be lawful for any person following the trade of cowkeeper or dairyman or purveyor of milk, to keep any swine in any cowshed or other building used by him for keeping cows, or in any milk-store or other place used by him for keeping milk for sale.

Existence of Disease among Cattle.

Section 15. If at any time disease exists among the cattle in a Dairy or Cowshed, or other building or place, the milk of a diseased cow therein—
- (*a.*) shall not be mixed with other milk; and
- (*b.*) shall not be sold or used for human food; and
- (*c.*) shall not be sold or used for food of swine, or other animals, unless and until it has been boiled.

Regulations as to Dairies, Cowsheds, Milk-Shops, &c., and as to Precautions against the Infection and Contamination of Milk in the Metropolis.

In pursuance of Section 13 of The Dairies, Cowsheds, and Milk-shops Order of 1885, the Metropolitan Board of Works [1] being the Local Authority for the Metropolis (except the City of London and the Liberties thereof) hereby made the following regulations—
- (*a.*) For the inspection of cattle in Dairies.
- (*b.*) For prescribing and regulating the lighting, ventilation, cleansing, drainage, and water supply of Dairies and Cowsheds in the occupation of persons following the trade of Cowkeepers or Dairymen.
- (*c.*) For securing the cleanliness of Milk-stores, Milk-shops, and of Milk-vessels used for containing milk for sale by such persons.
- (*d.*) For prescribing precautions to be taken by purveyors of milk, and persons selling milk by retail, against infection or contamination.

1. These regulations shall commence and take effect from and immediately after the third day of August, 1885.

Regulation for the Inspection of Cattle.

2. Every Inspector appointed by the Board under this Act is hereby authorised to inspect all cattle upon the premises of all persons registered by the Board under the Act.

Regulations for Prescribing and Regulating the Lighting, Ventilation, Cleansing, Drainage and Water Supply of Dairies and Cowsheds in the Occupation of Persons following the Trade of Cowkeepers or Dairymen.

Cowsheds.

3. Every Cowshed shall be well and sufficiently lighted by openings in the sides or roof, or by windows therein.

4. Every Cowshed shall be thoroughly ventilated by lantern-louvred ventilators in the roof thereof, or by louvred ventilators in the walls, or by openings in the sides or roofs.

5. In every Cowshed there shall be sufficient air-space for the health and good

[1] Now London County Council.

condition of the cattle therein, *i.e.*, there shall be for each animal kept in a separate stall a superficial space of at least 8 feet by 4 feet, and for two animals kept in one stall a superficial space of 8 feet by 7 feet; and there shall be an air-space of at least 600 cubic feet in respect of every animal kept in a Cowshed, where, taking into consideration the position and construction of the shed, there are perfectly satisfactory means of ventilation; but in other cases there shall be an air-space of 800 cubic feet in respect of every animal kept, and in any case the height of the shed in excess of 16 feet shall not be taken into account in estimating the air-space.

6. Every Cowshed shall be well paved with Stourbridge or other impervious brick, or other impervious material, set with cement properly bedded on concrete, with a proper slope towards a gully-hole, which shall, where practicable, be outside the shed; and such gully-hole shall communicate by an adequate drain of glazed stoneware pipes with the public sewer, and be trapped by an appropriate fixed trap, and be covered with a grating, the bars of which shall be not more than ⅜ inch apart; excepting that, not exceeding 3 feet of the foremost part of the stalls may be paved with chalk or other similar material.

7. Every Cowshed shall be provided with an adequate supply of water, and where there is not a constant water supply, with a slate, metal, or metallic-lined tank, properly covered and provided with an overflow or warning pipe, and with piping for conveying the water to the Cowshed; such tank to be so placed that the bottom thereof shall be not less than 6 feet above the floor level. Every such tank shall be of a capacity equal to 12 gallons of water for each cow lawfully kept; it shall have no communication with any water-closet or drain by means of a waste-pipe; and it shall be supplied with good and wholesome water, which, if practicable, shall be procured by the occupier from a public water company, and such tank shall be cleansed as often as is necessary for keeping the same in a clean condition.

8. Each stall or standing-place for cows in every Cowshed shall be provided with a water-trough or receptacle, constructed of or lined with hard, smooth and impervious material, and each such trough or receptacle shall be supplied with water by means of a pipe communicating with a water tank, or, in the case of a constant water supply, with the Water Company's pipes, and each such trough or receptacle shall also be provided with a waste-pipe or waste-hole in the lowest part thereof.

9. The inner walls, doors, and woodwork (except the partitions between the cows) of every Cowshed shall be covered with hard, smooth, and impervious material to a height of at least 5 feet from the floor of such Cowshed, and such hard, smooth, and impervious material shall not be covered with cement-wash, lime-wash, or other substance.

10. Every Cowshed shall be provided with properly constructed places or receptacles for storing any brewers' grains intended for the animals therein, and also places or receptacles for receiving the dung and litter from the Cowsheds, and such places or receptacles shall be constructed of or lined with impervious material and be properly drained; but no such places or receptacles shall be within, or communicate directly with, any Cowshed.

11. No water-closet, privy, cesspool, or urinal shall be within, communicate directly with, or ventilate into a Cowshed.

12. No dung, grains, or other substance from which effluvium is liable to be given off, shall be kept in any Cowshed; nor shall any dung, grains, or other substance as aforesaid be so kept that any effluvium therefrom can enter any Cowshed.

13. The upper parts of the inner surface of the walls of every Cowshed shall be thoroughly cleansed and limewashed in the months of March and September, and at other times within 7 days of the Board giving notice in writing that such cleansing and limewashing are necessary.

14. The floor of every Cowshed, and all troughs or utensils used for supplying the cows with food and water, shall be thoroughly cleansed with water at least once every day; and the portions of the walls, partitions, doors and other parts of the Cowshed within 5 feet of the floor shall be thoroughly cleansed as often as may be necessary for keeping the same in a clean condition.

15. All dung and offensive litter shall be carefully swept up and removed from every Cowshed at least twice every day, and shall be removed from the premises as frequently as may be necessary to prevent nuisance.

16. All utensils and vessels used by a cowkeeper for the reception, storage, or delivery of milk shall be thoroughly cleansed with steam or scalding water as frequently as may be necessary for keeping such vessels and utensils perfectly clean and sweet, and only clean water shall be used for this purpose.

17. Every Cowkeeper shall at all times employ such means, and adopt such precautions, as may be necessary for keeping any Cowshed in his occupation, and the cows therein, in a clean and wholesome condition.

Dairies.

18. Every Dairy shall be sufficiently lighted, and shall be thoroughly ventilated by louvred ventilators, ventilating shafts, or openings in the walls or roof.

19. Every Dairy shall be well paved with flagstones, concrete, or other suitable material, properly set in cement, and the inner walls thereof shall be covered with hard, smooth, and impervious material to a height of at least 6 feet from the floor of such Dairy, and such hard smooth, and impervious material shall not be covered with cement-wash, lime-wash, or other substance.

20. The floor of every Dairy shall fall or slope towards an opening in the walls thereof, leading to a properly trapped gully-hole outside such Dairy; and no inlet to a drain shall be within any Dairy.

21. Every Dairy shall be provided with an adequate supply of water, and, where there is not a constant supply, with a slate, metal, or metallic-lined tank, properly covered, and provided with an overflow or warning pipe, and with piping for conveying the water to the Dairy. The tank shall have no communication with any water-closet or drain by means of a waste pipe, and shall be supplied with good and wholesome water, which, if practicable, shall be procured by the occupier from a public water company, and such tank shall be cleansed as often as may be necessary for keeping the same in a clean condition.

22. The floor of every Dairy, and the portions of the walls and other parts of the Dairy within 6 feet of the floor thereof, as well as all fixtures and tables therein, shall be cleansed with water as frequently as may be necessary for keeping such Dairy, fixtures, and tables, in a thoroughly clean and wholesome condition, and the ceilings and the upper parts of the inner surface of the walls shall be thoroughly cleansed and limewashed as frequently as may be necessary for keeping the same in a clean condition.

23. All utensils and vessels used by a Dairyman for the reception, storage, or delivery of milk shall be thoroughly cleansed with steam or scalding water as frequently as may be necessary for keeping such utensils and vessels perfectly clean and sweet, and only clean water shall be used for the purpose.

24. Every Dairyman shall, at all times, employ such means and adopt such precautions, as may be necessary for keeping any dairy in his occupation, and the utensils and vessels used by him for containing milk, in a clean and wholesome condition, so as to preserve the purity of such milk.

REGULATIONS FOR SECURING THE CLEANLINESS OF MILK-STORES, MILK-SHOPS, AND MILK-VESSELS USED FOR CONTAINING MILK FOR SALE BY PERSONS FOLLOWING THE TRADE OF COWKEEPERS OR DAIRYMEN.

25. Every Milk-store or Milk-shop, as well as all fixtures and tables therein, used in connection with the keeping or sale of milk, shall at all times be kept in a cleanly condition.

26. All utensils and vessels used for the reception, storage, or delivery of milk, shall be thoroughly cleansed with steam or scalding water as frequently as may be necessary for keeping such utensils and vessels perfectly clean and sweet, and only clean water shall be used for the purpose.

27. Every person following the trade of Cowkeeper or Dairyman shall, at all times, employ such means and adopt such precautions, as may be necessary for keeping the utensils and vessels used by him for containing milk in a clean and wholesome condition, so as to preserve the purity of such milk.

REGULATIONS PRESCRIBING PRECAUTIONS TO BE TAKEN BY PURVEYORS OF MILK, AND PERSONS SELLING MILK BY RETAIL AGAINST INFECTION OR CONTAMINATION.

28. Every Purveyor of milk, or person selling milk by retail, shall immediately on any outbreak of infectious or contagious disease within the building or upon the premises in which he keeps milk, or amongst the persons employed in his business, give notice of such outbreak to the Board at their Office in Spring Gardens.

29. Every Purveyor of milk, or person selling milk by retail, shall immediately on such outbreak coming to his knowledge, remove all milk for sale, and all utensils for containing milk for sale from such building; and shall cease to keep milk for sale or to sell milk in such building until the same has been disinfected and declared by the Medical Officer of Health for the district to be free from infection.

30. Every Purveyor of milk, or person selling milk by retail, shall not keep milk for sale in any place where it would be liable to become infected or contaminated by gases or effluvia arising from any sewers, drains, gullies, cesspools, or closets, or by any offensive effluvia from putrid or offensive substances, or by impure air, or by any offensive or deleterious gases or substances.

31. Every Purveyor of milk, or person selling milk by retail, shall only keep milk for sale in clean receptacles; and all utensils used in connection with the keeping or sale of such milk shall be at all times kept clean.

32. Every Purveyor of milk, or person selling milk by retail, shall at all times employ such means, and adopt such precautions, as may be necessary for preserving the purity of milk, and for protecting it against infection or contamination.

REVOCATION OF FORMER REGULATIONS.

33. The Regulations made by the Board in pursuance of the Dairies, Cowsheds, and Milkshops Order of July, 1879, are hereby revoked.

NOTE. ANY PERSON GUILTY OF AN OFFENCE AGAINST THE FOREGOING ORDER OR REGULATIONS, IS LIABLE TO A PENALTY OF FIVE POUNDS, AND IN THE CASE OF A CONTINUING OFFENCE, TO A FURTHER PENALTY OF FORTY SHILLINGS FOR EACH DAY AFTER WRITTEN NOTICE OF THE OFFENCE FROM THE BOARD.

(194) *Tanning.*

The hides converted into leather by the tanner are divided by the trade into three classes, viz:—

(1) Fresh English hides, known technically as "market hides."

(2) Salted hides, mainly from S. America.

(3) Dry hides, these come from S. America, the Cape, India and other places (kips).

These different classes all require variation in treatment but the essential process at the basis of all the modifications is as follows:—

(1) Liming. This is the first process, the skins being soaked in pits containing lime and water.

(2) Unhairing. The hair loosened by the lime is removed.

(3) "Fleshing." The hide after well washing in clean water to remove the lime, is "fleshed," that is to say the loose inner tissue

of the hide is sliced off with a very sharp curved knife. The matters sliced off are called "fleshings" and are sent to the glue maker.

(4) Rounding. That is the shoulders and irregular jagged parts are cut off to be separately dealt with, the small scrips being sent to the glue maker. This operation performed, the technical name for the hide is a "butt."

(5) The "butts" are put into clean water and soaked for a few hours to get rid of any lime still adhering. If the "butts" are intended to be converted into "uppers" or soft leather they next go into a "cleaning pit;" this is a pit containing a solution of pigeons' dung, called "grainers," which softens the material. Instead of pigeons' dung, sometimes diluted urine is used, or fowls' dung or weak ammonia water. Probably the rationale of the action of the dung is the development of ammonia. The grainers are used cold.

(6) "Scudding." All superfluous water and dirt are removed by a special instrument and the small hairs still remaining shaved off with a sharp knife.

(7) "Splitting." Skins which are to be split are sent to a machine which separates them into two layers.

After these preliminary operations the actual tanning process begins, the butts being now sent through a series of "floaters" and "dusters." The floaters are pits of tan liquor of gradually increasing strength, after passing which the skins go into the "dusters," which consist of pits containing tan liquor of 25° strength of the barkometer. The butts being laid in these pits are sprinkled over with crushed bark. The butts go through three or four such liquors, remaining a week in each. Other very similar operations follow, that is they are laid in pits of increasing strength, the whole process lasting as long as ten months.

The sources of nuisance from tanneries are: the passage to and fro of more or less offensive material such as imperfectly cured foreign hides; the putridity of "old soaks"—these not unfrequently become horribly offensive, especially when they are being cleaned, the most offensive being not the liquor but the deposit at the bottom. Added to these the scraping processes, the handling of the hides when transferring from one lime pit to another, and the running of old soaks into the drains. In some

places they have got rid of waste tan by burning, and this has caused nuisance. There may also be nuisance from general untidiness and uncleanliness.

The remedies for these causes of complaint are pretty obvious. In the first place, in the conveyance of offensive skins or other debris to and from the tan yard, covered carts should alone be used, nor is there any reason why a disinfectant should not be applied; the ordinary disinfectants will not hurt the skin nor injure its properties as regards tanning. Old soaks before being cleaned out can certainly be disinfected by iron sulphate or other cheap substance. It has been found, notably in Bermondsey, that attention to little details and great cleanliness confines the smell to the immediate neighbourhood of the yards, so that houses a little way off are but little if any affected. There has been no injury to health actually proved, but an ill-managed tan-yard, one that smells offensively 50 or 60 yards beyond the works, must be considered in itself a nuisance, one that fairly comes under the term of an "offensive trade."

(195) *Leather Dressing.*

There is a distinction between a leather dresser and a tanner—the leather dresser only deals with "pelts," the tanner with bullocks' hides.

The only operation in leather dressing calling for comment is the one known as "puering." At a certain stage the pelts are soaked in a solution of dogs' dung, technically called "pure or puer." In the summer the solution is used at the ordinary temperature of the air, in winter it is warmed. The "puer," as might be anticipated, has an abominable odour, and unless this process is performed in a suitable shed so constructed that the contaminated air sweeps up either into a lofty chimney or through a fire, a nuisance is likely to be created.

(196) *Manufacture of Chamois Leather.*

In the making of chamois leather it is necessary to work fish oil (generally cod liver oil) into the skin; afterwards the skin is dried in a hot chamber; at 120° the odour of acrolein and fish oil is usually very perceptible. The remedy should complaint arise

is obvious, viz., to insist on arrangements to carry on the oiling in sheds properly constructed, so that the foul vapours are either led into a shaft so as to discharge into the air at a sufficient height or are swept into a furnace fire.

(197) *Glue-making.*

The manufacturer of glue boils out the animal gelatin from the following materials.

(*a*) Wet. Sheep pieces or "spetches" from fellmongers, "fleshings" from the leather dressers and tanners, the "roundings" of hides previously limed, portions of bones to which tendons are attached, ears of animals, clippings of salted and alumed skins used for covering cricket bat handles, &c.

(*b*) Dry. Damaged pelts, salted ox feet, calves pates, horn sloughs (that is, the core or pith of horns), the clippings and roundings of parchment, glue pieces from fellmongers, leather dressers and tanners, and other similar substances.

These matters are first "limed" and the lime afterwards well washed out with water. The matters are then boiled, the fatty matters being skimmed off the top, and the warm liquid glue run into shallow troughs and allowed to solidify. The solidified mass is then cut into slices.

Nuisance is liable to arise from the offensive nature of the raw material, and the process of boiling is accompanied by a good deal of odour. In one case there seems to have been fair grounds for ascribing direct injury to health from emanations from a glue manufactory.

This case is related by Ballard [1] in the following words: "Probably the high rate of mortality in the population immediately exposed to the effluvia arising from Hunslet Works just mentioned, has been due to this cause. Dr. Goldie, Med. Officer of Health for Leeds, in whose district the works are situated, is decidedly of opinion that such is the case. He tells me that during six years ending December, 1875, in an estimated population of 1,935 persons, not exceptionally poor or overcrowded, and situated in a comparatively open part of the borough, the mean annual mortality from all causes amounted to 35·6 per 1,000, while that from the five zymotic diseases—small-pox, scarlet fever, measles, 'fever,'

[1] Ann. Report Local Gov. Board. Med. Off. Report. 1876.

and diarrhœa, amounted to 9·12 per 1,000. Taking the whole of the Hunslet ward in which this little colony is situated, the annual death-rate from all causes during the same six years varied from 27·0 to 29·9, the mean being 27·9, and the death-rate from the five zymotic diseases mentioned varied from 4·6 to 6·0, the mean being 5·4. The annual mortality of the whole borough during the same six years varied from 26·4 to 28 5 per 1,000, and that for the five zymotic diseases mentioned from 3·6 to 5·9 per 1,000. Dr. Goldie tells me from his knowledge of the district that he is not aware of any conditions of locality or character of the population that could possibly account for so great a mortality about the glue works other than that of the presence of the offensive works themselves."

The greatest source of nuisance is without doubt accumulations of "scutch," that is the deposit left in the pan after running off the glue; besides this there are, as before stated, the emanations from the boiling, and the fleshings are apt to putrefy, especially if a greater store is obtained than can be immediately used. It is stated that the best way to deal with a stock of fleshings which cannot be at once utilized is to dry them, and if this cannot be done the next best thing is to stack them, alternate layers of lime and fleshings being piled in a well drained spot. The method adopted to prevent nuisance from the vapours given off from the glue pots in boiling is to operate in closed vessels, each pot having a pipe leading the steam into the furnace flue. In some places the "scutch" instead of being carried off for manure is first boiled up with acid, and the fat it contains extracted by skimming the residue is utilized as manure. No accumulation of offensive scutch should of course be permitted. The general rules and regulations to be put into force in dealing with such manufactories, may be gathered from the London County Council's bye-laws, which are as follows:—

LONDON COUNTY COUNCIL.

THE SLAUGHTERHOUSES, &c. (METROPOLIS), ACT, 1874, 37 *and* 38 *Vic.*, c. 67.

BYE-LAWS for regulating the conduct of the business of a Glue and Size Manufacturer, and the structure of the premises on which such business is being carried on; and the mode in which application is to be made for sanction to establish such business anew; within the limits of the Metropolis (except the City of London and the liberties thereof).

In pursuance of the Slaughterhouses, &c. (Metropolis), Act, 1874, by which the Metropolitan Board of Works[1] are constituted the Local Authority for the Metropolis (except the City of London and the liberties thereof), the said Metropolitan Board of Works, for the purposes of these Bye-Laws called the "Board," do hereby make the following Bye-Laws :—

Bye-Laws for Regulating the Conduct of the Business.

1. Every Glue and Size Manufacturer shall cause all moist fleshings and other material liable to decomposition, which may be kept or stored upon his premises, to be kept or stored only in such part or parts of his premises as are properly paved with asphalt, concrete, or other suitable jointless material, and covered with a water-tight roof; and he shall keep or store such material in such manner that no offensive effluvia or vapours therefrom shall escape into the external atmosphere.

2. Every Glue and Size Manufacturer shall cause every process of his business in which any offensive effluvia, vapours, or gases are generated, to be carried on in such manner that no offensive effluvia, vapours, or gases shall escape into the external atmosphere in such a way as to create a nuisance; and he shall cause all such offensive effluvia, vapours, or gases to be effectually destroyed, or discharged into the atmosphere at a sufficient elevation to render them inoffensive.

3. Every Glue and Size Manufacturer shall cause all scutch or refuse from the boiling pans, and all refuse, residue, or other matter from which offensive effluvia or vapours are evolved or are liable to be evolved, to be placed in properly closed receptacles, or to be otherwise dealt with in such manner as to prevent any offensive effluvia or vapours therefrom escaping into the external atmosphere.

4. Every Glue and Size Manufacturer shall cause all scraps of glue and size, and all litter composed of fleshings, trimmings, clippings, and other matters liable to become decomposed, to be constantly gathered or swept up and placed in proper receptacles.

5. Every Glue and Size Manufacturer shall cause the floor of every place in which glue or size is boiled, and of every place in which any process of the business (except the drying and packing processes) is carried on, to be thoroughly cleansed with water at least once in 24 hours; and he shall cause the premises to be constantly provided with an adequate supply of water for the purpose.

6. Every Glue and Size Manufacturer shall cause every inner wall of the premises on which his business is carried on to be kept at all times thoroughly clean and in good order and repair. He shall cause every inner wall and every ceiling in every part of his premises, where any process of boiling, cooling, cutting, or washing may be carried on, to be thoroughly washed with hot lime-wash in the month of March in every year, and from time to time thereafter, as often as may be necessary for the purpose of keeping such part of the premises in a cleanly and wholesome state.

7. Every Glue and Size Manufacturer shall cause every vessel, receptacle, utensil, or instrument provided or used upon, or in connection with, the premises on which his business may be carried on, to be kept, when not actually in use, at all times thoroughly clean, so as to prevent the emission of any offensive smell from such vessel, receptacle, utensil, or instrument.

8. Every Glue and Size Manufacturer shall afford access to every part of the premises on which his business is carried on to every Member and Officer of the Board, authorized in writing under the hand of the Clerk of the said Board, at any reasonable time during the hours within which such business may be carried on.

9. Every person offending against any of the foregoing Bye-Laws shall be liable for every such offence to a penalty of £5; and in the case of a continuing offence to a penalty of £1 for every day during which the offence may be continued after the conviction for the first offence.

10. Every Court of Summary Jurisdiction as defined in the Slaughterhouses, &c., Metropolis, Act, 1874, may, as a penalty for the breach of any of the foregoing Bye-Laws, by summary Order, suspend or deprive any person altogether of the right of carrying on the business of a Glue and Size Manufacturer.

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[1] Now London County Council.

Bye-Laws for Regulating the Structure of the Premises.

11. Every Glue and Size Manufacturer shall cause every floor upon which any process of his business (except the drying and packing processes) is carried on, in any part of his premises to be properly covered with a layer of concrete, or other suitable jointless and impervious material, laid (in the case of a ground floor) upon a suitable bottom of at least four inches in thickness. He shall cause such floor to have a proper slope towards a channel or gully; and shall cause every part of his premises wherein any such floor may be constructed to be effectually drained by adequate drains communicating with a public sewer. He shall also cause every drain to be properly trapped, and the entrance thereto to be covered with a fixed grating, the bars of which shall not be more than three-eighths of an inch apart.

12. Every Glue and Size Manufacturer shall cause his premises to be provided with appliances capable of effectually destroying all offensive effluvia, vapours, or gases arising in any process of his business, or from any material, residue, or other substance which may be kept or stored upon his premises; or with such appliances as shall be effectual for drawing off and discharging such effluvia, vapours, or gases, into the atmosphere at a sufficient elevation to render them inoffensive.

13. Every Glue and Size Manufacturer shall cause all needful works and alterations to the premises to be forthwith done and executed as and when the same shall become requisite, but shall not allow any alteration whatsoever to be made in respect of the structure of the premises, without the consent of the Board.

14. Every person who shall not comply with any of the foregoing Bye-Laws relating to the structure of the premises shall be guilty of an offence, and shall be liable, for every such offence, to a penalty of £5, and in the case of a continuing offence, to a penalty of £1 for every day during which the offence may be continued after the conviction of the first offence. Provided always that the foregoing Bye-Laws for regulating the structure of the premises shall not, until after the expiration of twelve months from the date of the confirmation of the Bye-Laws be deemed to apply to any premises where at such date the business of a Glue and Size Manufacturer may be carried on.

Bye-Law for Regulating the Mode of Application for Sanction to New Establishment of the Business.

15. Every person who may apply to the Board for sanction to establish anew the business of a Glue and Size Manufacturer, shall furnish with the application a plan of the premises and sections of the buildings in which it is proposed to carry on such business, such plans and sections being drawn to a scale of a quarter of an inch to the foot, and showing the provision made, or proposed to be made, for the drainage, lighting, ventilation, and water supply of such premises, and shall also furnish a key plan of the locality, showing the buildings and streets within one hundred yards of the premises, drawn to a scale of five feet to the mile.

Dated the First day of August, One thousand Eight hundred and Seventy-nine.

(198) *Nuisance from Fried Fish Shops.*

The frying of fish is frequently complained of. The fish are fried in dripping or other fatty matter; should the fat burn, acrolein is produced, but, as a rule, the fumes are not specially irritating. The stove where the fish is fried should be provided with a suitable hood or other appliance to carry off the volatile materials; there ought to be no difficulty in carrying the vapours evolved either through a fire or into a chimney shaft high enough to prevent the odour being offensive to neighbours.

(199) *Roasting of Vegetable Substances, such as Malt, Chicory, Coffee.*

There is considerable odour in all these cases. The roasting is usually performed in revolving cylinders, the cylinders being inclosed in casings to which the heat is applied. The nuisance may be greatly reduced, if not altogether prevented, by carrying the vapours themselves into a tall chimney shaft, and by the use of proper hoods connected with the chimney.

(200) *Nuisances from the Manufacture of India-rubber.*

The crude india-rubber is boiled, washed in a machine called a "masticator," incorporated with flowers of sulphur or antimony sulphide, and goes through various other processes. It is subsequently vulcanized by either the American process or the English process. The American or Goodyear process is chiefly mechanical, but in the English process a solvent called "solvent naphtha" is used.

The nuisances produced are a peculiar india-rubber odour, together with the odour of tar-oil and sulphuretted hydrogen. These odours are perceptible at times at distances of a quarter of a mile. According to Dr. Ballard, the processes concerned in creating nuisance are as follows :—

(1) The boiling of the rubber, the steam having an "india-rubber" odour.

(2) The several processes in which naphtha are used.

(3) The discharge of steam from the vulcanizers.

(4) The drying of sheets of vulcanized india-rubber upon steam chests after washing them, the process giving an odour of burning rubber.

The methods proposed to prevent these nuisances are as follows :—

(1) The boiling of the rubber to be conducted in closed vessels, and the steam to be condensed or burnt up in a fire.

(2) The naphtha condensed, as is done in Messrs. Moseley's works, or else passed, as in Messrs. Quin's factory at Leyland, into a scrubber supplied with creasote oil; the oil absorbs the naphtha, and the naphtha may be subsequently recovered by distillation.

(201) *Flax Retting.*

The flax plants are soaked in pits under water, and the infusion thus produced is allowed to ferment; this process is called "retting." Afterwards the plants are spread out in a field to dry. The fermentation is productive of nuisance, for the process is decidedly offensive. Carbonic acid and other gases are produced in considerable quantities, but according to analyses by Professor Hodges, of Belfast, no sulphuretted hydrogen can be detected. The odour of the flax pool is ascribed to small quantities of butyric and other volatile fatty acids. The "grassing" is still more productive of nuisance; for here large quantities of offensive matters are spread out in the fields, and the vapours impregnate the air for a long distance.

(202) *The Manufacture of Oxalic Acid from Sawdust.*

Sawdust is introduced into a semicircular iron pan heated by a fire beneath, and the sawdust is mixed with a strong solution of potash or soda, or both. The mixture is evaporated down to a pasty mass and constantly stirred. During this part of the process vapours are abundantly given off, which are variously described as "sickly" or as "disagreeable," but no direct injury to health has been proved.

When the material is dry, it is lixiviated with water, and the alkaline oxalate crystallized out. A solution of this crude oxalate is precipitated by means of lime, and the oxalate of lime is boiled with sulphuric acid so as to set the oxalic acid free; the solution of oxalic acid is crystallized out, and to aid in bleaching it, before crystallizing a little nitric acid is added. During the treatment with sulphuric acid, very irritating acid fumes are given off.

The remedy for the nuisance during the evaporation down with alkali is evidently to cover the vessel in which the process takes place, and to convey the fumes away either to a tall chimney shaft or through a fire.

The evolution of corrosive acid fumes can be dealt with by leading the fumes to a coke tower in which the coke is kept moist by a stream of water.

(203) *The Manufacture of Paper from Esparto Grass.*

The esparto grass is boiled with a solution of caustic soda; the liquor from this boiling is in some places turned into the nearest stream, polluting it and destroying the fish present; in other places it is concentrated by evaporation, incinerated, and the soda recovered.

Esparto liquid is of the colour of strong tea, is alkaline from the soda in solution, is strongly reducing, and emits a very peculiar and offensive odour. It should never be permitted to be run into a stream or ditch near inhabited places.

During the process of incineration for the recovery of the soda there is a strong empyreumatic odour. There may also be nuisance from the evaporation in the old-fashioned way by boiling it down in shallow pans.

In the best arrangements, such as "Roeckner's patent evaporator" and the "Porion-Davis' evaporator," there would, however, seem to be little cause of complaint.

(204) *The Manufacture of Wood Pulp.*

The manufacture of wood pulp is very similar to the above. Chips or shavings are heated with steam under pressure, a solution of caustic soda being added. The soda is generally recovered as in that from esparto liquor. Nuisance has been experienced from offensive steam, and from the turning of the hot liquid into the public sewer.

(205) *Distillation of Wood for the Purposes of obtaining Wood Naphtha and Pyroligneous Acid.*

Wood, exhausted dye-woods, or sawdust are distilled in ovens, cylinders, or other forms of retorts, and the volatile products condensed. Nuisance arises from the evolution of uncondensed gases, and from operations involved in changing the retorts and in luting them.

In Bowers's apparatus for the distillation of sawdust, the pipe conveying the vapours for condensation often gets blocked and has to be cleared; the operation takes little time, but during the short interval there is abundant escape of gaseous products.

The recommendations of Dr. Ballard with regard to the remedy of these nuisances are briefly as follows:—

To burn up the uncondensed gases, or to carry them up a tall chimney shaft.

The nuisance arising from an escape from Bowers's apparatus, in clearing the exit pipes, may be obviated by stopping the feed rollers for five minutes before the opening of the pipes; under these circumstances no escape of vapour takes place.

The nuisance caused in drawing the charge may be lessened by hastening the process. The charge from a cylinder should be drawn into boxes fitted with covers, in which after luting down it may be left to cool, or which may be used to convey it to the underground brick chambers technically called "extinguishers." But in the large square ovens, the process of drawing the charge is necessarily a long one; here the most feasible plan seems to be to construct the "extinguisher" as close as possible to the oven, so that the charge may be directly raked out into it; if in addition to these precautions the ovens and shoots opened into a closed building ventilated by means of a wide pipe leading to a pipe flue or tall chimney shaft with good draught, such an arrangement would minimise the danger of external nuisance.

When the charge is drawn into boxes, there should be no delay in luting down the covers. The boxes should not be carried into the open air until the luting is finished. The buildings into which the ovens open should be closed, and arrangements made for ventilating them into a fire or tall chimney.

(206) *Nuisances depending chiefly on the Production of Acrolein.*

Acrolein is a product of the decomposition of glycerin; hence whenever a fat or oil is heated to a decomposition temperature it is produced. Acrolein is a light, volatile liquid of low specific gravity, boiling-point about 120° F. It is extremely irritating to the eyes, throat, and to the mucous membranes of the bronchial tubes. It is readily combustible.

Acrolein vapours are given off during the bleaching of palm oil, the boiling of linseed oil (which is in point of fact decomposing rather than boiling), the manufacture of oil varnishes, the manufac-

ture of leather cloth, enamelled table covers, the enamelling of leather, the manufacture of floor cloth and linoleum, the recovering oil from oily clothes and shoddy, the distillation of palm oil, cotton oil, "foots" and other kinds of grease.

In all these processes, at some stage or other, oils and oily matters are heated to a high temperature, and as a consequence irritating fumes are given off.

The principle to be adopted is to either condense the fumes by conveying them through pipes where they can be washed by a spray of water, or to lead the tube into a furnace fire so as to burn the fumes up. In certain cases it seems to be necessary to boil acrolein-producing substances in an open vessel, and in that case the adoption of the principle of Heywood's and Lloyd's arrangement for collecting and condensing vapours from varnish-making may be adopted. The apparatus is as follows: A is the boiling pot; on the top of this is fitted a funnel-shaped cover, B; from this cover a pipe, C, is led, which pipe is attached to an extracting fan D, and the fan drives the vapours to a series of condensing tubes E, to a fire, or to a high chimney shaft as occasion requires. The consequence of this arrangement is that there is always a strong down-current through B into A to supply air rushing through C, and no vapour can escape into the air except by the channel provided for it.

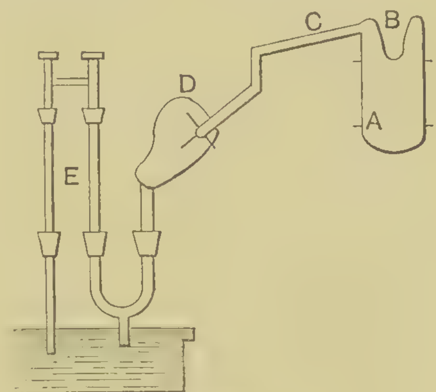


Fig. 45.

(207) *The Manufacture of Coal Gas.*

Coal is submitted to destructive distillation in a close retort, volatile and gaseous matters are expelled, and a carbonaceous residue left behind. A brief description of the outlines of the process is as follows:—The coal is placed in a retort, and the retort heated to dull redness. The volatile substances in the ordinary manufacture pass up a pipe called "the ascension pipe," the upper end of which is curved downwards so as to discharge near the floor of a large horizontal pipe called "the hydraulic main"; in this pipe water

and tarry matters condense to a thick liquid which forms at the end of the ascension pipe a trap or liquid seal (In some places, as at the Fulham works, the hydraulic main is dispensed with.) The gas at a high temperature streams from the hydraulic main into a series of cooling pipes called condensers; the pipes are simply exposed to the air, and it is found not advisable to cool the gas below 60° or 65° F. The condensers free the gas from a good deal of watery vapour, from tar, and from as much ammonia as the deposited water is capable of absorbing; the condensed substances fall into a space below, and are received into the tar well. In works of any size, the gas now passes to the exhauster or air pump as crude coal gas; containing as impurities, carbonic acid, ammonia, sulphuretted hydrogen, bisulphide of carbon, some cyanogen compounds, and small quantities of tarry matters, with aqueous vapour. The more special purifying processes now commence. First the gas passes to a "scrubber," *i.e.* a tower or cylindrical vessel of considerable size in which by means of ingeniously arranged trays or other contrivances the gas is made to pass through water, and is thus deprived of all ammonia, besides some proportion of the other impurities already detailed. The "scrubbed" gas next passes into the lime purifiers—that is, boxes on which are trays of hydrate of lime. The lime combines with the carbonic acid gas to form carbonate of lime, and with sulphuretted hydrogen to form calcic sulphide. When all the lime is turned into calcic carbonate and sulphide, and the gas still streams in, then the carbonic acid gas decomposes the calcic sulphide, and sulphuretted hydrogen is given off, until the whole of the lime becomes carbonate of lime. Hence lime alone cannot be conveniently used to cleanse the gas of sulphuretted hydrogen. The gas freed from carbonic acid gas is next passed into the oxide of iron purifier; here it is deprived of the sulphuretted hydrogen, which combines with the iron, forming iron sulphide. Where by the conditions under which the company is governed, the gas must be purified from carbon disulphide, it is got rid of by interposing a small purifier filled with calcic sulphide between the lime purifier and the oxide of iron; with this substance bisulphide of carbon forms a sulpho-carbonate.

The process described is not followed in all the works, some one or other detail varying; thus ammonia which has escaped the

scrubber is sometimes absorbed in sawdust alone, or sawdust mixed with sulphuric acid. Instead of oxide of iron, sulphate or chloride of iron is sometimes used.

There is some nuisance in the drawing of the retorts, an operation permitting of the escape of a certain amount of gases, and attendant with the production of offensive steam, the red-hot coke being raked out into water; but this seldom travels beyond the works. The chief source of nuisance is the emptying of the lime purifiers, and the conveyance of the spent lime to its destination. Nuisance from the lime purifiers is much aggravated by improper working. In small country places the writer has seen purifiers changed so seldom that practically crude coal gas was delivered to the consumers. Directly the purifier gets at all foul from sulphur compounds it should be emptied. Dr. Ballard, in his report on effluvium nuisances, has described in great detail the method in use at the Fulham works, where, despite the large scale of the works, by carefully covering up with sacking those portions of the foul lime in a purifier not in actual process of being dug out, and having special covers for every part of the subsequent operations—covers, that is, for the trucks, and for the barges into which the spent lime is conveyed—and by previously watering the foul lime in the purifier to prevent the rising of dust, this usually offensive operation is done with but little odour.

In one case, in which the writer was a witness, a gas-works was a considerable source of nuisance to a watering-place, from defects in the construction of the works themselves; in particular the scrubber had only a wooden top; through this wooden top abundance of gas streamed, blackening lead paper. Sometimes there is nuisance from the revivification of the spent oxide, defects in the scrubbing process allowing ammonia compounds to reach the iron oxide; in such cases, as the oxide always heats in the revivification, much ammoniacal vapour may be given off.

(208) *The Manufacture of Sulphate of Ammonia and of Sal Ammoniac.*

The ammoniacal liquor from the gas-works is mixed with lime, distilled, and the ammonia received into either sulphuric or hydrochloric acid until saturated, and the salt crystallized out.

Nuisance may be caused during the transference of the liquor from the gas-works, from the storage of the liquor, or during the manufacturing process. The main cause of complaint is the escape of sulphuretted hydrogen. The methods in use for abatement of this nuisance are mainly two: (1) burning the fumes, (2) absorbing them by chemical agents. The sulphuretted hydrogen and other matters are burnt by carrying them either into a special furnace or into the same furnace which distils the liquor; in either case, the vapours, consisting of sulphurous acid and other gases, should be carried into a tall chimney shaft; otherwise one nuisance will only be replaced by another. The absorption of SH_2 is effected by lime, or by hydrated oxide of iron mixed with sawdust. The latter is preferable.

(209) *Distillation of Tar.*

Coal tar, mixed with more or less ammoniacal liquor, is distilled in suitable stills. The products are (1) "light oils," floating in water, from which benzole and solvent naphtha are obtained; (2) "heavy oils," or creasote oils, sinking in water, and containing cresylic and carbolic acids; (3) anthracene oil, still heavier than creasote oils; and lastly, (4) pitch.

The sources of nuisance, according to Dr. Ballard, are as follows:—

1. The reception of the tar in uncovered barges, and its transference to the tanks or storage receptacles at the works; the offensive odour is chiefly from sulphide of ammonium.

2. The escape into the atmosphere of offensive distillation products. These come off mostly towards the end of the distillation.

3. The escape of a more or less dense white vapour when hot pitch is run off from the still or pitch oven into the pitch bay, or a similar vapour from the pitch bay or tubs before they cool.

4. The escape of offensive vapours from the pitch oven.

5. The combustion of creasote oil as fuel for the stills, where the arrangements for its proper combustion are incomplete.

All these nuisances have been dealt with successfully at properly designed and conducted works, *e.g.* like those of Messrs. Burt, Boulton, and Haywood, Silvertown. The main points are transference of the crude material in air-tight vessels, absorption of

sulphide of ammonium by hydrated oxide of iron, passing the gases through water and then burning them up in the furnace fire, running the pitch into a closed vessel to cool, and lastly, where creasote oil is used as a fuel, burning the oil in furnaces specially constructed for that purpose.

(210) *The Manufacture of Carbolic Acid.*

The carbolic oil obtained from the distillation of coal tar is treated in an iron tank with caustic soda, which dissolves out the carbolic and cresylic acids, and leaves "tar oils" unacted upon. The caustic soda solution is separated from the "tar oils" by syphoning, and then the alkaline liquid is supersaturated with sulphuric acid; thereupon the crude carbolic and cresylic acids separate, and the acids are ladled off and distilled. The distillation is fractional and is carried to dryness, the residue in the retort consisting of a light coke which subsequently is used as a fuel.

Nuisance is liable to be caused by the odour of carbolic acid, by the escape of offensive gases towards the end of the distillation,

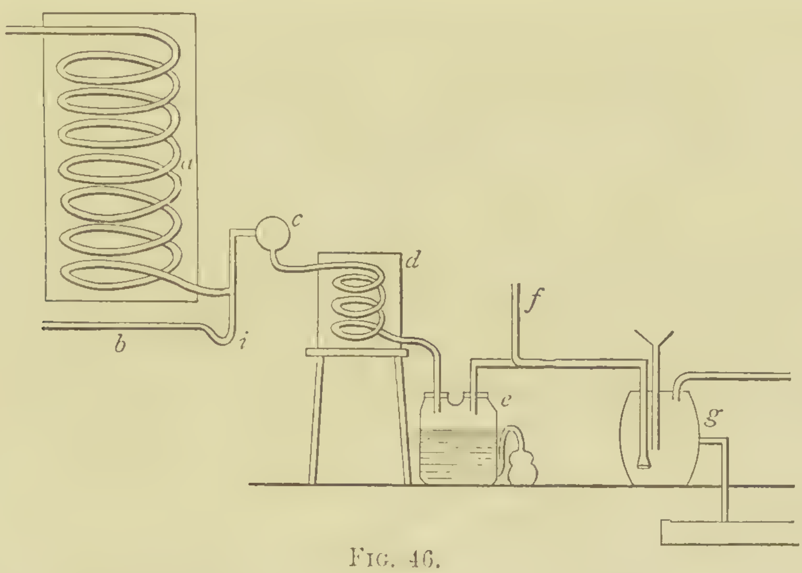


FIG. 46.

and by the removal of the coke from the retorts. The general odour of carbolic acid is much lessened by receiving the condensed liquids into covered vessels. The offensive gases are dealt with at Mr. Lowe's works at Reddish in the following way :—The

pipe from the worm condenser *a* divides into an ascending and a descending branch; the descending branch, *b*, carries the condensed liquids and is trapped by a syphon at *i*, while the ascending pipe delivers gases into a 6-inch main pipe, *c*, which runs along the whole range of stills. From the main a pipe conveys the gases to a small worm condenser, *d*, and from this to a stoneware bottle, *e*, which receives any liquid matter condensing; a pipe from *e* is supplied with a steam exhauster jet, *f* which causes a greater or less vacuum in the gas main, and drives the gases onwards through water or milk of lime, contained in a cask, *g*, whereby sulphuretted hydrogen is arrested, and from this washer a pipe conveys any gases not arrested into the ash-pit of a fire. This arrangement of Mr. Lowe's seems generally applicable to offensive distillations, and is highly ingenious.

Nuisance occasioned by the removal of coke from the retorts is said not to occur, provided the distillation is complete, and the coke only removed when cold. There ought to be no difficulty in passing the products of combustion through scrubbers of coke through which water trickles.

(211) *The Manufacture of Alkali.*

The materials used are common salt, sulphuric acid, limestone and coal. The salt is decomposed by sulphuric acid, assisted by heat. The reaction here is a simple case of double decomposition, sulphate of soda, is formed and hydrochloric acid escapes. The crude sulphate of soda, termed technically "salt cake," is mixed with crushed limestone, or chalk and coal, and heated strongly, the ultimate result being a mixture of sodic carbonate, calcium sulphide and unburnt carbon; the latter gives the mass a black colour, hence it is termed technically "black ash." The black ash is treated with water which dissolves out the sodic carbonate; the residue is known as "tank waste."

The manufacture has been the subject of special legislation, the more particularly with reference to the acid fumes or gases which are necessarily produced. These are defined by the Act to be sulphuric acid, sulphurous acid, nitric acid, or other noxious oxides of nitrogen, sulphuretted hydrogen and chlorine. At the present time great improvements in the apparatus for "scrubbing" or

washing the issuing gases have generally reduced the nuisance from the acid gases, and the fact that special inspectors are appointed to see that the requirements of the Act are observed rather take the matter out of the hands of the medical officer of health and his subordinates.

What, however, will directly concern the sanitary chief, is nuisance arising from tank waste. These form mounds, embankments, and even small hills of an artificial earth consisting of various compounds of sulphur and calcium, the oldest layers being oxidized to a greater or less degree to sulphite and sulphate of calcium, while the more recent layers have a large proportion of sulphide, and if from any cause moistened are liable to give forth sulphuretted hydrogen.

The chief source of waste heap nuisance is the soluble matter, which is "a sulphuretted compound of calcium of indefinite composition, but which is mainly composed of sulphide of calcium, partly converted by oxidation into hyposulphite of calcium, and holding in solution with it a considerable but indefinite quantity of sulphur." The solution of the sulphur matter occurs from being washed by the rain, from being lixiviated by springs, or, as at the St. Rollox works, the heaps being situated on the banks of a tidal river, and being washed by its waters as it rises and falls.

In recent years successful attempts have been made for the utilization of the waste, the sulphur contained in them being extracted by appropriate chemical treatment.

In Mond's process, air is blown through the fresh tank waste, and by this means the sulphur compounds oxidized to sulphite and sulphate; these soluble compounds are lixiviated out by means of water, the aqueous solution is then treated by steam and hydrochloric acid, sulphur is precipitated and allowed to subside, it is afterwards collected, and forms a very pure kind of sulphur. The process is not productive of nuisance in theory, but in practice there is no doubt that sulphuretted hydrogen is not unfrequently evolved.

Mactear's process in use at the St. Rollox works is as follows: The sulphur heaps, which are situated in this instance on ground permeated with springs, supply a large and regular amount of liquid holding in solution calcic sulphite and hyposulphite. Hydrochloric acid is added, and both salts decomposed; in the

decomposition of the hyposulphite, sulphur is thrown down and sulphurous acid evolved; in the decomposition of the sulphide sulphuretted hydrogen is evolved, but this gas coming in contact with the sulphurous acid is immediately decomposed, and sulphur falls, so that if there is always a sufficiency of the hyposulphite to evolve enough sulphurous acid to decompose all the sulphuretted hydrogen, there is no nuisance, and the whole of the sulphur of the sulphide is recovered. If there is not a sufficiency in the liquid itself the requisite quantity of the hyposulphite is added.

(212) *The Manufacture of Picric Acid and the Manufacture of Aniline and Aniline Colours.*

The different processes in use for the manufacture of picric acid, of nitro-benzole, of arsenic acid, of magenta and of the aniline dyes generally, are all liable to permit the escape of nitrous acid or other acid fumes. Since however the escape of any acid is a distinct loss to the manufacturer, in all well-managed works they are condensed as much as possible.

The best method to obviate nuisance seems to be to pass the gases through water, and lastly through fire.

A heavy odour of essence of myrbane often pervades aniline works, this is due to small leakages.

(213) *The Manufacture of Sulphuric Acid.*

Sulphuric acid is made by burning either sulphur, cupreous pyrites, mundic, sulphur holding oxide of iron from the gas works, or from sulphuretted hydrogen. The sulphurous acid produced by the burning of these forms of sulphur or sulphides is oxidized into sulphuric anhydride in large lead chambers by means of the higher oxides of nitrogen, set free by the action of sulphuric acid on sodic nitrate. The weak acid is subsequently concentrated in platinum stills and in glass retorts.

Nuisance may be caused by the escape of sulphurous acid gases and by the higher oxides of nitrogen. The gases may escape from (*a*) the chimney; (*b*) leakages in the burners and escape in the opening of the feeding doors; (*c*) leakage from the lead chambers arising from defective joints; (*d*) concentration of the chamber acid:

c) evolution of acid fumes from accidental breaking of a glass retort. Escapes of gas by the chimney will not occur in large works where the Gay Lussac and Glover towers are used. The Glover tower is essentially a coke tower, and the principle of its action is that when strong sulphuric acid charged with nitrous acid is mixed with either water or weak acid, most of the nitrogen compounds are given off. The gases from the burners stream up this coke tower and meet two streams of acid, viz., weak chamber acid and acid charged with nitrous fumes from the Gay Lussac tower; the reaction mentioned above takes place, and the nitro-sulphuric acid is almost completely denitrated. The gases pass on into the chambers, the denitrated acid passes into the Gay Lussac tower, which is a leaden scrubber packed with coke; the strong denitrated acid being forced up to the top of this tower, trickles down through the coke, absorbing any nitrous fumes, and thus the acid is turned into nitro-sulphuric acid, the destination of which is as before to the Glover tower. Hence there is a perpetual circulation, and theoretically the same nitrogen could be used over and over again; leakages and some other chemical changes prevent the entire realization of this. It is however clear that where these towers are used no nitrous fumes should escape from the chimneys.

The other sources of nuisance are more or less remediable by proper fittings, suitable stoking, suitable covers, condensing arrangements and obvious precautions.

(214) *The Manufacture of Salt.*

This manufacture consists in the evaporation of brine which has been raised from salt mines. The chief salt mines are in Cheshire and Worcestershire. The brine is first pumped into reservoirs to deposit and then run into large shallow evaporating pans. Each pan is heated either directly by a fire placed underneath it or by a system of flues. The flues from the fires of the salt pans usually terminate in a number of low chimneys from 30 to 60 feet in height, the reason assigned for not replacing the short chimneys by one tall shaft, is the danger to the tall shaft from the subsidence of the land, which as is well known is constantly taking place in salt districts.

Salt works are productive of two kinds of nuisance, viz., the

evolution of black smoke at a low level, and of acid fumes. The acid fumes are produced (1) by the decomposition of magnesic chloride; (2) by sulphurous acid produced by burning the slack; (3) by a reaction between sulphurous acid gas and sodic chloride; (4) decomposition of sodic chloride by the silica of the bricks, silicate of soda being formed and hydrochloric acid produced. The acid fumes are therefore mainly hydrochloric acid with some sulphurous acid.

There is also some nuisance caused by waste heaps. Several patents have been taken out for a more economical method of salt manufacture enabling manufacturers to dispense with the use of open pans altogether. So long as the system of open pan evaporation continues the abatement of these nuisances is difficult.

The sulphurous acid can be much diminished by the use of a good form of slack or coal containing only a small proportion of sulphur; the fear of injuring the long chimney shafts from subsidence is said not to be so great as the manufacturers make out, at all events light long sheet iron chimneys lined with fire brick and secured by wire rope stays could surely be used?

(215) *The Manufacture of Chloride of Lime (Bleaching Powder).*

The ordinary process is the decomposition of hydrochloric acid by manganese dioxide; the chlorine evolved is conducted to chambers where hydrated lime is exposed to its action in thin layers. The decomposition takes place in a square chamber made of Yorkshire flags, and the reaction is aided by means of steam. The residue is a strong acid solution of manganese chloride.

The Weldon process of making chlorine differs from this in recovering the manganese and using it over again. The solution of manganese chloride is neutralized by means of limestone, which precipitates the impurities, viz., oxide of iron, alumina and carbonate of lime; these are allowed to settle, and the clear liquid, containing calcic chloride, manganese chloride and some calcic sulphate, is transferred to an iron cylinder where it is mixed with milk of lime; manganese protoxide is precipitated as a thick black mud. Air is blown through this mud, which effects an oxidation, oxidizing the protoxide into binoxide of manganese.

In the Deacon process hydrochloric acid gas is passed at a high

temperature over bricks saturated with sulphate of copper solution; under these circumstances the acid gas is decomposed, the hydrogen forming with the oxygen of the air, water and the chlorine passing on in the free state. The gas is washed with water and dried by means of strong sulphuric acid. It is then pure enough to be used to saturate the lime.

The Deacon process, Dr. Ballard says, is free from nuisance outside the works.

The source of nuisance from bleaching works is the escape of chlorine from leakage, and from chlorine being only mechanically, not chemically, combined with the lime, from the chambers themselves, and lastly from the packing and transferring the powder to casks or other receptacles.

One method of reducing the "chamber" nuisance is as follows:—the door of the chamber is slightly opened, and by means of a fan the chlorine atmosphere is driven into another chamber in which there are layers of fresh lime; another good plan is to use divided chambers, that is, chambers divided into two by a partition, and then when one part is saturated, remove the partition and thus allow the excess of chlorine to be absorbed.

It has also been proved that with proper arrangements the transference into casks need cause no nuisance. For instance in Messrs. Deacon's works the powder is transferred direct to the cask from the chamber through a tube of sacking.

(216) *The Manufacture of Glass.*

In the manufacture of glass, especially that of the poorer kinds, sulphate of soda and common salt are heated with silica and other substances, the result being that sulphuric and hydrochloric acids are expelled. There is besides generally a considerable amount of nuisance from smoke. Where the works are large, the amount of acid sent into the atmosphere is of course proportionate; for instance at the St. Helen's plate glass works more than 190 tons of sodic sulphate are decomposed weekly.

No way of abating the acid emanations from glass works which will not interfere seriously with the trade itself has yet been devised; of course neither sodic sulphate nor sodic chloride are essential to use at all, it would be far better to employ sodic

carbonate, but it is said the great competition, especially with foreign manufacturers, prohibits the use of the dearer material.

A good deal has been effected to remedy the smoke nuisance, *e.g.* with the Siemens gas furnace there is no nuisance from smoke. There are also several improved furnaces which with careful stoking consume most of their own smoke.

(217) *The Calcining of Ironstone and Tap Cinder.*

Ironstone whether in the form of "clay band" or "black band" is calcined in order to drive off carbonic acid, to peroxidize the iron, burn off the sulphur, and reduce the bulk of the ore. The calcining is done either in clamps or in kilns. The slag drawn from puddling furnaces is treated similarly.

In both instances there is nuisance from smoke and sulphurous acid gas. Kiln burning is much less offensive than clamp burning, and where the nature of the stone will allow of this process to be used, it should be insisted upon.

(218) *Hardening of Steel Springs and Saws.*

In the tempering of various steel articles the red hot steel is plunged into a bath of oil. The result is the evolution of irritating fumes of acrolein and other volatile substances. The nuisance can be remedied like others of the same kind, viz., by conducting the evolved vapours through a furnace fire and thus burning them up.

(219) *The Calcining of Spelter.*

In the smelting of zinc ores, containing sulphur such as blende, copious sulphurous acid fumes are evolved. There is also much dust in the form of oxide of zinc produced. Dr. Ballard states that in one instance the nuisance from the fumes was successfully abated by carrying them up a flue 300 yards long and then into a tall chimney shaft. This effectually removed the vapours from the vicinity of inhabited houses.

(220) *Galvanizing Iron.*

The iron is first chemically cleaned by means of acid, it is then dipped into a bath of melted zinc. During this process hydrogen is evolved, and very frequently some hydrocarbons, the hydrogen

uniting with the carbon of the iron. Should the iron contain sulphur or phosphorus, then sulphuretted or phosphuretted hydrogen gases are likely to be eliminated. Where chloride of ammonium is sprinkled upon the bath from time to time then chloride of arsenic is evolved. In most cases there is indeed an arsenical odour from the fumes during the galvanizing of iron. The spent pickle is a strongly acid solution of chloride of iron.

There can be no question that the fumes from galvanizing iron are directly injurious to health, and should be removed from the works by suitable fans, hoods, and flues, and either properly condensed or discharged at a considerable height into the upper layers of the atmosphere. If the spent pickle is likely to damage the sewers it should be neutralized by means of limestone.

(221) *Tin Plate Manufacture.*

The plates are first pickled in acid. The pickle consists of slightly diluted oil of vitriol heated up to boiling point by means of steam. After pickling, the plates are immersed in a series of dipping pots, the first of which is filled with palm oil, and the others contain melted tin covered with a layer of palm oil.

The emanations from tin plate works consist of acid fumes, of odours of palm oil and acrolein. There is also more or less hydrogen gas evolved, the gas having a peculiar odour. The practice seems to be to use a number of small chimneys, instead of collecting the fumes into one large shaft. So long as the traditions of the trade remain unbroken, great difficulty will be necessarily experienced in effectually dealing with the vapours. There is little doubt that the general principles of conveying the various fumes collected by hoods and flues to scrubbers and then to a furnace fire, would arrest the acid and burn up the organic emanations.

The strongly acid spent pickle is often concentrated by boiling for the purpose of crystallizing out the iron sulphate it contains; this is necessarily accompanied by the evolution of acid fumes. Any nuisance from this source can be readily obviated by covering the concentrating vessels and condensing the fumes in a scrubber. Where the spent pickle is not dealt with in this way it should not be cast down the sewers until neutralized with limestone or some form of lime.

(222) *Tin Burning.*

Tin burning is the burning by fire of refuse heaps containing old tins for the purpose of extracting the solder they contain. If the refuse does not already contain enough combustible matter, wood shavings are added in alternate layers. From the ashes solder and other saleable matter are picked out by hand. Tin burning generally gives rise to much offence, the vapours are often most irritating, especially when the refuse contains an oily matter, such as paint, there is also a large volume of smoke given off at a low level. Tin burning is only practised by the very poor in large cities, hence the crude method employed. Of the nuisance of the process there can be little doubt.

(223) *The Calcining of Arsenic and Arsenical Ores.*

In the roasting of arsenical pyrites and in the refining of arsenic large volumes of sulphurous acid are given off, the sublimed arsenic also is a real danger to the work people. It appears, unfortunately, that attempts to wash the sulphurous acid fumes, which are always mixed with a large volume of air, have not been successful, for the washing always interferes with the draught of the furnaces. Where it can be done, the uncondensed fumes should be discharged at such an elevation and at such a distance from inhabited houses that they shall be thoroughly dispersed before they have time to fall in such quantities as to occasion nuisance.

(224) *The Smelting of Copper Ores.*

In the various complicated operations in use for the smelting of copper ores containing sulphur, there are volatile emanations consisting of sulphurous acid gas, arsenious acid, and, if fluorine be present, fluoride of silicon, with dust and smoke. The vapour well-known as "copper smoke" is a mixture of these volatile and dusty matters. The copper will occasionally travel some distance, but the arsenic has not been discovered save in the immediate neighbourhood of the works.

According to Mr. Hussey Vivian's evidence before the "Noxious Vapours Commission" the principle to be adopted in lessening the

fumes from copper works, is to have large deposit flues so as to lessen the velocity of the vapour, the flues terminating in lofty shafts.

(225) *Lime Burning.*

Lime is either burnt in a close or open kiln. Nuisance may arise from lime burning if low class fuel is used, especially fuel containing much vegetable or animal matter, also if the gases, which always contain some considerable proportion of carbon oxide, get entrance into adjacent dwellings. In Dr. Ballard's report on effluvium nuisances there is a distinct case of chronic carbon oxide poisoning from this cause. Lime burned in close kilns, the vapours being carried into the upper part of the atmosphere, appears to be productive of little or no nuisance.

(226) *Manufacture of Coke and Breeze.*

In principle the manufacture of coke and breeze is nothing more than destructive distillation of carbonaceous matter by the agency of heat, the air being partially excluded; water, compounds of hydrogen and carbon, and volatile matters generally, are driven off, and there is left, if the process is stopped at a certain time, an impure carbon with incombustible mineral matters. The manufacture is either done in heaps, "pile coking," or in ovens. Pile coking is most productive of nuisance, dense volumes of smoke are emitted at a low elevation with sulphurous acids and other irritating gases. The amount of sulphurous acid gas depends on the amount of sulphur in the fuel which is coked, some classes of fuel containing but a small quantity, other classes containing much pyrites and therefore a large quantity. The mean quantity of sulphur in coal is a little under 1 per cent., but some of the Welsh coal contains as much as 5 per cent. of sulphur. One method of pile coking is to build a hollow, permanent, brick dome, perforated at intervals; around the base are iron pipes for the admission of air extending radially like the spokes of a wheel; the coal to be coked is piled up around the dome, the whole being covered with coke dust, such a pile is lighted at the centre and burns slowly to the circumference. The burning is continued for five or six days, and then the fire is extinguished by covering the

heaps with damped coke dust. Dr. Ballard describes a fairly effectual means of mitigating the nuisance from coke-pile burning, the invention of Mr. E. Jones; it briefly consists in connecting a flue with the central dome, drawing off the products of combustion by means of a fan through underground flues, and condensing the products by passing them through a water jacketed condenser. These condensed products are commercially valuable.

When coking is done in ovens, the vapours are passed into a tall chimney shaft, and are thus discharged at a sufficient elevation to abate more or less the nuisance.

(227) *Brick Burning.*

Bricks are burnt either in clamps or kilns. Clamp burning, is burning the bricks in a quadrangular pile. The green bricks made of clay and mixed with a small proportion of ashes being arranged in layers alternating with breeze. The breeze is set alight by means of small fires of wood and coal.

(*a*) *Kiln Burning.*—In kiln burning no combustible substance is mixed with the brick material. The bricks are burned by the aid of coal. The kilns are either open, that is the smoke finds its way from the top of the kiln into the atmosphere, or the kilns are provided with a special flue for discharging the smoke.

(*b*) *Clamp Burning.*—Clamp burning is especially offensive. The emanations are watery vapour, thick smoke, the usual gases of combustion, very often sulphuretted hydrogen, and certain pyroligneous matters which have an offensive odour. Where, as is often the case, household refuse is used containing animal and other organic matter, the odour is intensely disagreeable. The emanations are often acid, irritating to the mucous membranes and injurious to vegetation.

The fumes from burning bricks differ in composition very much in the different stages of the process, the clay used, and the fuel employed. Clamp burning as the most offensive process should be entirely prohibited in the neighbourhood of large towns. Kiln burning by careful stoking, by the use of certain special kilns, and by the aid of a long chimney shaft, can be carried on with but trifling offence.

(228) *Ballast Burning.*

Ballast burning is converting stiff clay by the agency of heat into a bricklike material for use on the roads. The clay is usually burned in heaps mixed with breeze and ashes. It is, without doubt, a great nuisance. Dr. Ballard remarks, "Should it at any time be held essential that clay should be burned where the burning is likely to be a nuisance, it should be burned in such a way as to bring the effluvia under control. I see no reason why it should not, under such circumstances, be burned in a kiln with due provision against nuisance from the empyreumatic vapours and smoke emitted. If it is absolutely necessary that ballast should be burned in heaps, it appears to me that the method adopted by Mr. Jones (see page 306) to prevent coking in heaps, or some similar method, would be applicable. If it is worth while to burn the clay at all it ought also to be considered worth while to do it inoffensively.

(229) *The Manufacture of Portland Cement.*

Two kinds of hydraulic cement are in use—the one, "Roman cement," made from the *septaria* nodules found in the London clay formations; the other, "Portland cement," made from an artificial mixture of clay and limestone. In the manufacture of the Roman cement the stones are calcined in open kilns, like limekilns, and there is but little nuisance. The manufacture of Portland cement has, however, often been complained of, and has formed the subject for injunction. The chalk and clay are mixed under water, and then the mixture is either run into depositing-tanks, or when only a small quantity of water is used (Goreham process), the substances are ground together. In either case a wet mud is produced, which is technically called "slurry." The slurry has to be dried, and then burned in kilns. The chief nuisance is in the burning, and especially if this is done in open kilns. The emanations consist of gases, some of which, like carbon dioxide and sulphuretted hydrogen, are poisonous. In certain cases, when the clay used contains much nitrogenous matter, it appears to be definitely proved that either hydrocyanic acid or a volatile cyanide is produced. At Southampton, for instance, the fume from a cement

works was observed to colour the gravel in its neighbourhood blue, and the blue colour Dr. Dupré found to be produced by cyanide of iron; moreover, the gases drawn from the kiln were found to contain volatile cyanides. The emanations from a cement-kiln vary according to the different stages; this is well shown in some analyses by Dr. Russell and Mr. Fleming, made in 1877, of gases from an open kiln at Greenhithe:—

TABLE XXXIII.

	FIRST STAGE.	SECOND STAGE.	THIRD STAGE.
	Combustion commencing. Gases rank. Plenty of white smoke. Temp. not very high.	About half way to greatest heat. Gases very rank and strong smelling. On sucking out gases, water and tarry matter passed over. The water not acid; at this period most smell.	Full red heat. Not much smell or moisture. White dust in tube.
Oxygen	17·03	11·70	2·35
Carbonic acid .	3·89	4·27	20·56
Carbon oxide .	1·34	6·27	8·59
Nitrogen . . .	77·74	77·76	68·50
	100·00	100·00	100·00

Besides gaseous products there are also sublimations and dusty matter; these are composed of soot, cement dust, and sulphates of lime and potash, chlorides of the alkalies, with silica, alumina and some lime compounds. Some of these collect as a white deposit in the neighbourhood of the kiln.

Dr. Ballard's report gives good grounds for saying that emanations from open kilns during the process of manufacturing Portland cement are positively injurious to health.

There have been attempts to mitigate the nuisance of cement-making in three directions—viz., washing the fume with water; passing it through fire; and delivering it at a high elevation by means of a tall chimney shaft. The first method seems not to have been very successful; burning the fume has to a certain extent been found to answer, but the best method of dealing with it, according to experience, is to discharge it from a tall chimney shaft, that is one from 150 feet to 200 feet high.

(230) *The Firing of Pottery—Salt-glazing.*

In salt-glazing, the articles of clay are subjected to a high heat with common salt. A decomposition of part of the salt takes place: silicate of soda is formed, producing a glaze, and hydrochloric acid gas escapes with the portion of salt in excess; there is also always some sulphurous acid gas from the fuel employed, and more or less smoke. It has been hitherto found impracticable to arrest the acid vapours by scrubbers, because their interposition interferes with the draught necessary to properly fire the articles, and the only feasible means to mitigate the nuisance is to convey the vapours into the upper regions of the atmosphere by a tall chimney shaft.

SECTION VII.

DISINFECTION.—DISINFECTANTS.

CHAPTER XXII.

EXPERIMENTAL METHODS FOR TESTING THE VALUE OF A DISINFECTANT.

(231) *Distinction between Disinfectants and Antiseptics.*

A TRUE disinfectant is a chemical substance which is capable of killing by its poisonous action a pathogenic, or disease-producing germ; it is therefore synonymous with "germicide." Disinfection is to be distinguished from "destruction," as, for instance, by fire or by the corrosive action of strong mineral acids; a genuine disinfectant does not necessarily change the structure of the tissues or bacteria submitted to its influence.

Antiseptics are substances that arrest the development of germ-life; all disinfectants are also antiseptics, if employed in quantities insufficient to destroy life, but antiseptics are not necessarily germicidal.

The elements modifying disinfection are *quantity* of disinfectant in relation to the thing to be disinfected, *temperature* and *time*. In other words, the disinfectant must be of sufficient strength—must act on the substance to be disinfected for a sufficient period of time.

(232) *Temperature.*

Temperature is important, for the writer has proved that, *e.g.* 1·15 per cent. of lutidine, acting for twenty-four hours at 15°, failed to disinfect a thread infected with bacterium termo, but ·5 per cent. at 35°.5 of lutidine disinfected absolutely. The element of time is all important; nevertheless, the experiments of Cash have proved that a disinfectant in a too dilute state may act for a lengthened time on pathogenes without any effect, but if the

disinfectant be of such a strength that it is capable of disinfecting at all, the longer the time *cæteris paribus*, the more complete the disinfection.

(233) *Experimental Methods.*

There are two methods by which a chemical agent may be tested:—First of all, to find out whether it is a disinfectant at all; and secondly, if it should be a disinfectant, what dose or strength should be used?

1. *Inoculation into Animals of Disinfected Matter.*—The virus of a disease, or a pure cultivation of a pathogene, is taken, such as tuberculosis, mouse septicæmia, anthrax, submitted to the action of a disinfectant of a definite strength for a definite time and temperature, and then the product is injected into an animal known to be susceptible. At the same time a similar quantity of the undisinfected virus is injected into another animal, called "the control," and the effects noted. This method of experiment is by far the most satisfactory and conclusive.

2. *Testing "Cultures."*—The second method is of great utility, because it enables an observer to arrange disinfectants in their order of strength, and essentially consists in submitting cultivations of microbes to the action of disinfectants, and then ascertaining their power of development in nutrient soils. The writer has employed certain processes for this purpose, which he has thus described ("Studies of Disinfectants by New Methods," *Proceedings of the Royal Society*, 1886).

(234) *The Drop Method.*

Sterilised pure water is infected with a few c.c. of gelatin liquefied by the bacterium; measured volumes of this infected water are then added to measured volumes of the disinfectant, and the whole allowed to act for a definite time. A drop of this liquid is then added to from 10—20 grams of the nutrient gelatin first liquefying it at a very gentle heat. As the proportion of the weight of the drop to the weight of the nutrient gelatin varies from about 1 : 500 to 1 : 1000, the dilution is in most cases sufficient to reduce any antiseptic or inhibitory action of the minute quantity of the chemical agent in the drop itself to a minimum, so as to exercise no appreciable effect.

(235) *The Thread Method.*

In the thread method capillary glass rods are made by drawing out ordinary glass tubing in the blow-pipe flame, these are tipped with sealing-wax, and to the wax a little bit of sterilized cotton wool is made to adhere.

The end of the rod thus prepared is infected with the bacterium by a short immersion in a pure cultivation and then placed in the disinfectant for a definite time. The rod on removal is soaked for a little time in sterilized water until all trace of the disinfectant has been removed.

The rod thus charged and purified is next inserted into a mass of solid nutrient gelatin in a test-tube, and put on one side at the ordinary temperature of the atmosphere, protected of course from external contamination by a suitable plug of sterilized wool. Whether the process used is the "drop" or the "thread," in each case "control" experiments are made with threads infected with the bacterium, but which have not been submitted to disinfection.

Enumeration of Colonies.—This is an entirely different method of procedure. The number of colonies in a gram of sewage or other suitable liquid are carefully determined by a modification of known methods.

The same sewage is then treated by substances the disinfectant properties of which form the subject of inquiry, and the number of colonies capable of growing in a nutrient soil, representing the micro-organisms which have escaped destruction, again enumerated.

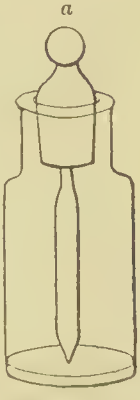


FIG. 47.

The only special apparatus used requiring description is the "drop-bottle" and the "rings and plates."

The Drop-bottle.—The figure represents its shape and size, the capacity is about 25 c.c. The stopper is hollow and terminates in a pipette; it has a pin-hole at *a*, which can be closed by the finger.

The Glass Plates and Rings.—The glass plates are 4 by 2 inches square, the rings 4 inches in diameter, $\frac{1}{8}$ inch thick, and $\frac{1}{4}$ inch high. The plates have a ground surface the size of the ring thickness; the rings are cemented to the plates in the following manner. After heating the rings and plates in a hot air oven for many

hours a little peptone gelatin is run on to the ribbon of ground surface, the ring adjusted, and the whole allowed to cool in a glass chamber formed by a small dish covered by a slightly larger one; at the bottom of the dish is some filter-paper moistened with a solution of mercuric chloride. The plates are not used until the gelatin cement has perfectly set. The plates are ruled by means of a diamond into squares for the purpose of easy enumeration.

Solid substances, such as ferrous sulphate, may be weighed and dissolved in definite quantities of the sewage; in other cases solutions of known strength are mixed with the sewage.

The method of cultivation is as follows:—A small quantity, whether of diluted or disinfected sewage, is transferred to the previously cleansed and sterilized drop-bottle, the bottle and its contents carefully weighed, then by means of the pipette stopper one or two drops spotted on to the surface of the glass cell formed by the plate and ring already described; the weight of the drops is ascertained by reweighing the drop-bottle.

Ordinary nutrient gelatin liquefied at a gentle heat is run from a Lister flask into the glass cell, and mixed equally with the drops by inclining the plate in different directions. During these several operations dust is excluded as far as possible by covering the glass cell by a second glass plate, merely shifting the plate sufficiently on one side to allow the insertion of the nozzle of the Lister flask or the point of the pipette. The cells thus charged are placed in the moist chamber; the gelatin rapidly sets, and at the end of from three to five days the colonies of growth are counted in the usual way and their general nature determined.

The weight of the drop or drops taken may vary from 20 to 100 mgrs., the gelatin in which the drop is cultivated from 15 to 20 grams, so that the minute quantity of disinfectant contained in the drop itself is diluted from 200 to 1000 times. This amount of dilution with the comparatively weak percentages of most disinfectants save those approaching corrosive sublimate in power reduces the action of the disinfectant on the gelatin, the cultivating soil—to a minimum, so that practically as soon as the micro-organisms still surviving are floated into the nutrient gelatin they are removed from the sphere of disinfectant influence, the following is an example of this method:—

Two quantities of sewage were respectively treated with phenol and cresol, so that the mixtures were equivalent to 1·9 per cent. and allowed to act for twenty-four hours; the mean of two strictly concordant experiments gave the following as the number of colonies which at the end of four days could be enumerated—

	No. of colonies per gram of the sewage taken.
Phenol	33,333
Cresol	33,410
The control	1,490,000

CHAPTER XXIII.

DISINFECTION BY HEAT.

(236) *Experiments of Parsons and Klein.*

VALUABLE experiments have been made in this country by Drs. Parsons and Klein, as to the details of heat disinfection; the following is condensed from Dr. Parsons's report on the subject. (*Supplement, 14th Annual Report, Local Government Board.*)

The infective materials employed were :—

(1) Blood of guinea pig dead of anthrax, containing spore free bacillus anthracis. (2) Pure cultivation of b. anthracis in rabbit broth, without spores. (3) Spore holding b. anthracis in gelatin cultivation. (4) Cultivation of bacillus of swine fever (infectious pneumo-enteritis of the pig) in pork broth. (5) Tubercular pus, from an abscess in a guinea pig which had been inoculated with tubercle.

Strips of clean flannel were steeped in the respective infective fluids, dried in the air, wrapped separately and loosely in a single layer of thin blotting paper, and suspended in the centre of the apparatus in company with a thermometer, so placed that its bulb was close to the packets of infected material. The results of the disinfection were tested by inoculation of animals. Control inoculations with unheated portions of the same materials were also in all cases made.

(237) *Experiments with Dry Heat.*

They found that spores of anthrax lost their vitality after exposure for four hours to a temperature a little over that of boiling

water (212°—216° F.); or for one hour at a temperature of 245° F. Non-spore-bearing anthrax, as well as the bacilli of swine fever, were rendered inert by exposure for an hour to a temperature of 212°—218°, and even five minutes' exposure to this temperature sufficed to destroy the vitality of the former and impair that of the latter.

(238) *Experiments with Moist Heat.*

(*a*) *Boiling Water.*—Dr. Klein found that spore holding bacillus anthracis was killed by boiling for so short a space as one minute.

(*b*) *Steam at* 212°.—The experiments were conclusive that it destroyed all contagia; in one instance only, was there room for doubt, this was in the case of highly resisting anthrax spores exposed to steam for five minutes only.

(239) *On the Penetration of Heat into Articles Submitted for Disinfection.*

Experiments were made to ascertain how far the enclosing of infective objects in blotting paper or test-tubes plugged with cotton wool hindered the full access of heat to them. Two similar registering thermometers were taken; the bulb of one was tied up in a single layer of thin white blotting paper, that of the other was placed in a test-tube $\frac{7}{8}$ inch wide, in such a manner as not to touch the sides, and a plug of white cotton wool 1 inch deep was pushed into the tube around the stem of the thermometer, but not as far as the bulb. Both the paper and cotton wool were previously dried. The two thermometers were then suspended in a proper apparatus which need not be here described. It took two and a half hours before the thermometers thus covered attained the same heat as the naked thermometer. In a second experiment in which a thermometer was covered with a single layer of blanket; the blanket-covered thermometer marked 4° lower than the control at the end of two and a half hours.

The following tables give results of similar experiments on pillows, and show conclusively how difficult it is to secure the penetration of a dry heat sufficient for disinfection into the interior of such an article as a pillow. It can only be effected by

either employing a high degree of heat, or by continuing its employment during many hours, the length of exposure compensating for a lower degree of heat.

TABLE XXXIV.

1.—DRY AIR.

Description of Pillow.	Weight. lbs.	Temperature to which exposed °F	Apparatus	Time. hrs.	Temp. in centre. °F	Scorched or not.
Feather	5	312	Leoni	½	140	Scorched.
Flock	4	280	Langstaff	2	147	,,
Feather (tight)	3	344	Scott	4	138	,,
Flock	4	?	Fraser	1	134	,,
Feather (loose)	3	(above	,,	1	275	,,
Flock	6	275)	,,	2	138	,,
,,	4	?	,,	6	298	,,
,,	4¼	318	,,	1	136	,,
,,	3	250-260	Ransom	5½	227	Not Scorched.
Horsehair	?	276	Scott	1	149	,,
Feather	5	290	Taylor	1	122	,,

2.—MOIST AIR.

Description of Pillow.	Weight.	Temperature to which exposed. °F	Apparatus.	Time.	Temp. °F.	Readings of wet bulb maximum thermometer °F.
Flock	4	220-240	Bradford	2¼	217	184
,,	3¾	268	,,	1	252	212
Feather	5¼	295	Taylor	1	162	192
Flock	4¼	299	Fraser (portable)	1	188	189
,,	4¼	264	,,	1	209	192

3.—STEAM.

Pillow.	Weight. lbs.	Temperature to which exposed. °F.	Apparatus.	Temp. in centre. °F.	Time.	Pressure of steam above that of atmosphere.
Feather (tight)	6½	251	Lyon	185	½ hour	15lbs. constant
Same	,,	251	,,	212	½ hour	15lbs. once relaxed and then reapplied.
Feather	3¼	251	,,	237	½ hour	
Flock	3¼	240	Benham	171	2 min.	10lbs.
,,	3½	240	,,	234	10 min.	10lbs.
Feather	3½	240	,,	234	10 min.	10lbs.
,,	2¾	212	Bradford	182	10 min.	—
,,	2¾	252	,,	251	½ hour	22lbs.

(240) *Explanation of the Superior Penetrating Power of Steam.*

The superior penetrating power of high heat in the form of steam over hot air having been thus demonstrated, Dr. Parsons points out the cause of this as follows:—

(1) Probably the most important is the large amount of latent heat in steam. To convert 1 lb. of water at 212° F. into steam at 212° F., requires nearly 1,000 times as much heat as it does to raise 1 lb. of water from 211° to 212° F. Conversely a corresponding amount of heat is liberated when 1 lb. of steam at 212° F. is condensed into water at 212° F. When an object is heated by being placed in hot dry air, not only is no latent heat yielded up to it by the air, but on the other hand before the object can attain the temperature of 212° any water which it may contain (and all textile fabrics, even though dried at ordinary temperatures, retain a quantity of hygroscopic moisture) must be evaporated; in this evaporation heat passes into the latent form, and the attainment of the required temperature is thus delayed.

(2) When steam penetrates into the interstices of a cold body, it undergoes condensation in imparting its latent heat as aforesaid to the body. When condensed into water it occupies only a very small fraction (about $\frac{13}{100}$) of its former volume. To fill the vacuum thus formed more steam presses forward, in its turn yielding up its heat and becoming condensed, and so on until the whole mass has been penetrated. On the other hand hot air in yielding up its heat undergoes contraction in volume it is true, but only to a very small extent as compared with that undergone by steam in condensing into water. Thus air at 250° in cooling to 50° F. would contract to $\frac{5}{7}$ of its previous volume.

(3) The heat which is evolved in the moistening of a dry porous substance is another source of advantage on the side of steam. Pouillet (*Annales de Chimie*, II., xx., p. 141) has shown it to be a general law:—(1) That when a liquid wets a solid, there is a disengagement of heat. (2) That when a solid absorbs a liquid there is a disengagement of heat. The amount of heat liberated in the incorporation of a liquid into the substance of a solid is much greater than that liberated by mere superficial wetting; this is owing to the multiplication of points of contact. In proportion as a wetted substance is finely divided, the number

of particles which are moistened and take part in the evolution of heat is multiplied, while the number is diminished of those which not being wetted, do not give out heat but absorb it at the expense of others. Hence, porous organic substances, as being most finely divided, are those which in moistening evolve most heat. (Chemical reactions like the slaking of lime are of course excluded.) If a clinical thermometer be wrapped up in a few turns of flannel which has recently been highly dried before the fire and cooled, and the roll be held in the mouth and the expired breath forced through it, a temperature considerably over that of the breath will be found to be registered by the thermometer. In such an experiment Dr. Parsons found the thermometer to reach 110°·6 F., the temperature of the breath as taken by the same thermometer being 99°·2. If the flannel in which the bulb of the thermometer is wrapped have been dried merely in the air at ordinary temperature and humidity, an elevation of temperature above that of the breath will still be obtained, but of less extent than in the previous case; while if the flannel is damp no elevation at all will be obtained.

The following experiment shows that the same action takes place at higher temperatures.

A thermometer was wrapped in a few rolls of flannel, and was heated in dry air to 220° F. for some time; it was then allowed to cool a little, and as the mercury fell, the index was shaken down till it stood at 212° F. The dry roll of flannel was then placed in a tin cylinder and exposed for five minutes' steam at 212° F.; at the end of which time the thermometer included was found to register 239° F.

(4) The specific heat of steam is greater than that of air in the proportion of 30 to 23·7 or about 5 to 4; in other words 4 volumes of steam in falling 1° without condensing into water yield up as much heat to other objects as 5 volumes of air at the same temperature yield.

(5) The diffusion of two gases into one another takes place with a velocity inversely as the square roots of their respective densities. The specific gravity of steam, air being taken as 1 is ·623; hence the rate at which steam would diffuse into air as compared with that at which air would diffuse into steam at the same temperature would be as 100 is to 79, or about 5 to 4. Between air and air the rate of diffusion would be equal, or as 4 to 4; thus

excluding the influence of differences of temperature, steam would diffuse into air with a rapidity one-fourth greater than air would.

(6) The penetration of heat in the form of steam, is, Dr. Parsons maintains (contrary to Koch), aided by pressure. This seems to be proved by the following experiment made with a model of Lyons's apparatus.

A registering thermometer loosely wrapped in a sheet of cotton wool was exposed for half an hour to steam at 28 lbs. pressure = 273° F.; the index marked 270°. It stood equally high after exposures of a quarter of an hour and of five minutes, but after an exposure of three minutes only 260° was recorded. In another experiment a thermometer similarly wrapped, and another one naked were placed in the machine, and the door loosely closed; steam at 30 lbs. pressure was admitted into the casing, but into the interior of the chamber only sufficient to moisten the air of the chamber. After half an hour the naked thermometer registered 250°, the one in the cotton wool only 217°.

By relaxing the pressure of steam, and then reapplying the pressure from time to time, the penetrative power of the steam is greatly increased.

A pressure of steam 15 lbs. to the square inch above that of the atmosphere compresses the air in the interstices of the material to half its original volume, and thus the space originally occupied with cold air becomes partly occupied with hot steam; steam partly mixed with air occupying the interstices near the surface and air those in the centre. Equilibrium of pressure having been obtained, the interchange of air and steam particles and of temperature would take place comparatively slowly. On relaxing the pressure, however, the air again expands to its original volume, and thus becomes mixed with the steam, and on the pressure being reapplied the steam is forced further into the interstices.

Experiments are also given showing that hot moist air has an advantage over hot dry air.

(241) *On the Liability to Injury of Articles Disinfected by Heat.*

The modes in which injury may occur are somewhat different in the case of steam and that of dry heat. Dr. Parsons classifies the possible injuries under the following headings:—

(1) Scorching or partial decomposition of organic substances by

heat. In its incipient stage this manifests itself by change of colour, of texture, and weakening of strength.

(2) Overdrying, rendering things brittle.

(3) Fixing of stains so that they will not wash out.

(4) Melting of fusible substances, as wax and varnish.

(5) Alterations in colour, gloss, &c., of dyed and finished goods.

(6) Shrinkage and felting together of woollen goods.

(7) Wetting.

Overdrying can only occur of course when dry; wetting when moist heat is employed; scorching is more an effect of dry heat than of moist heat or steam.

(242) *Scorching.*

(1) Scorching occurs with different materials at different temperatures. It occurs sooner in woollen materials, such as flannels and blankets, than with cotton or linen; horsehair bears a high temperature, in fact the process of curling it for stuffing chairs is effected by exposing it to a temperature of over 300° F.

Most materials will bear a temperature of 250° F. without much injury, but when this temperature is exceeded signs of damage soon begin to show. Flannel and blankets exposed to steam at 260° for half an hour acquire a distinct yellow tinge, and their tensile strength is somewhat diminished. Exposed to a dry heat of 220° F. for four hours, or a steam heat of 228° for half an hour, white flannel acquired a slight yellow tinge, but its textile strength was not appreciably impaired.

Ransom[1] found that wool, cotton, linen, silk, and paper could be heated to 250° F. without injury if the action be only continued for three hours; 295° F. he found, if continued for three hours, to decidedly singe white wool, and less so grey and white cotton, and white silk and white paper and linen, but does not injure their appearance greatly. If the heat is continued for five hours at 295° then the articles mentioned are both singed and their appearance injured.

The experiments of de Chaumont,[2] of Vallin,[3] and of Koch and Wolffhugel,[4] give lower temperatures than those quoted as causing

[1] *British Med. Journ.*, Sept. 6, 1873.
[2] *Lancet*, Dec. 11, 1875.
[3] M. Vallin, *Traité des Désinfectants.*
[4] *Mittheilungen aus dem Kaiserlichen Gesundheitsamte.* Berlin, 1881.

change. Parsons's experiments are more definite, because the tensile strength was tested. The results are contained in the following table :—

Table XXXV.

Dr. Parsons's Experiments on Effects of Heat on various Fabrics.

Material.	Exposed to.	Time.	Shrinkage per cent.	Tensile Strength before and after.	Colour.
White flannel (length)	Steam 264° F.	½ hour	6·0	100 : 88	Distinct yellow tinge
,, (breadth)	,,	,,	5·7	100 : 88	,,
,, (length)	,, 228°	,,	5·4	100 : 97	Yellowish tinge
,, (breadth)	,, ,,	,,	4·1	100 : 96	,,
,, (length)	,, 212°	,,	5·8	100 : 92	Slight yellowish tinge
,, (breadth)	,, ,,	,,	6·0	100 : 100	,,
,, (length)	Dry heat 220°	4 hours	1·6	100 : 107	Yellowish tinge
,, (breadth)	,, ,,	,,	·8	100 : 98	,,
,, (length)	,, 280°	2 hours	2·0	100 : 100	Yellow tinge, dark in places
,, (breadth)	,,	,,	·4	100 : 95	,,
,, (length)	Simple washing	—	6·6	100 : 132	Very slight change
,, (breadth)	,,	—	7·4	100 : 102	,,
,, (length)	Boiling water	½ hour	8·4	100 : 85	Dirty yellowish change
,, (breadth)	,,	,,	6·9	100 : 95	,,
Tape (cotton)	Steam 260°	4 hours	?	100 : 82	Little alteration
,,	,, 251°	½ hour	1·4	100 : 80	,,
,,	,, 212°	½ hour	2·0	100 : 77	,,
,,	Dry heat 230°	4 hours	0·35	100 : 73	No discolouration, lost glaze
,,	,, 280°	2 hours	0·7	100 : 73	Slightly darkened
,,	Boiling water	½ hour	2·7	100 : 73	Lost glaze
Black cloth	Steam 251°	½ hour	0·9	100 : 100	No alteration
,,	,, 212°	½ hour	0	100 : 90	Slightly discoloured
,,	Dry heat 230°	4 hours	0	100 : 100	Slightly rusty as if from long wear
,,	,, 280°	2 hours	0·8	100 : 100	Slightly rusty, more marked
,,	Boiling water	½ hour	0	100 : 100	Discoloured; dye having run
White silk ribbon	Steam 251°	½ hour	2·1	100 : 100	No alteration
,,	,, 212°	½ hour	2·0	100 : 100	,,
,,	Dry heat 230°	4 hours	·7	100 : 87	No change in colour; less glossy
,,	,, 280°	2 hours	·35	100 : 60	Brownish tinge; scorched
,,	Boiling water	½ hour	1·00	100 : 100	Lost glaze
Kid glove	Steam 250°	½ hour			Shrivelled up and converted into a gelatinous substance, very hard when dry
,,	,, 212°	5 minutes			Ditto
,,	Dry heat 212°	1 hour			Unaltered
A felt hat	Steam 228°	5 minutes			Greatly distorted by softening of felt and disorganisation and shrivelling of leather lining
,,	Dry heat above 250°	1 hour			Unaltered
Feathers	Steam 260°	4 hours			Yellowish and brittle
Blankets	,, 251°	½ hour			Yellowish tinge
,,	Dry heat 240°—268°	2½ hours			Ditto somewhat hard and threadbare; puckered
Dyed silk ribbon various colours	,, 230°	4 hours			Unaltered
	Steam 251°	½ hour			Ditto

Scorching is especially liable to take place when the heat is in the form of radiant heat. In one of the experiments with different forms of apparatus, it was found that the ticking of a pillow was uninjured, although exposed to heat of 276° F. as tested by a thermometer laid beside it. In this case the pillow had been screened from the direct access of heat rays from the source of heat, whereas in other instances, in which the pillows were laid on wooden bars directly over the heated bottom of the chamber, it showed distinct stripes of scorching corresponding to the interspaces between the bars, although a thermometer laid beside it did not record a temperature any higher than, or even so high as, in the former case.

Scorching is brought about by radiant heat in two ways—First, textile articles, specially wool, are good radiators, as we may see by the copious deposit of dew or hoar frost which takes place upon them when exposed in the open air on a clear night, and therefore with converse facility they absorb the rays of heat, and are thus heated to a higher degree than the surrounding air. Secondly, in the chamber heated primarily by radiation the walls of the chamber and solid objects in its interior, such as shelves, bars, and hooks, become by absorption of heat-rays hotter than the air, and consequently organic substances, such as articles of dress, are liable to be burnt where they may chance to come in contact with the hot metal. On the other hand, if the chamber be heated by hot air warmed before its entrance, as in the Ransome stove, the walls of the chamber are no hotter than the air, and objects may come in contact with them without injury.

(243) *Over-drying.*

(2) Over-drying, short of actual scorching, renders many organic substances brittle; it is by this means that in pharmacy tough vegetable drugs, as roots, barks, and others, are prepared for grinding into powder. On the other hand, on exposure to moist air this brittleness is again lost; we know how the crispness of the new-baked biscuit is soon lost unless kept in a well-closed canister.

It was found by Dr. Henry, in his experiments, that the tensile strength of textile materials was weakened by exposure to dry

heat, but was in a great measure regained if the materials were allowed to remain in the air a day or two before testing.

M. Vallin[1] took hair and wool, which had been previously well beaten, and exposed them for four hours to a temperature of 248° F. Portions beaten again immediately after being taken out of the stove yielded a layer of detritus, while other portions, beaten only after a lapse of twenty-four or forty-eight hours, when they had time to regain their hygroscopic moisture, did not yield more waste than unheated portions of the original material.

It is evident that injury from over-drying can easily be avoided by allowing the materials which have been subjected to dry heat to remain in the air long enough to recover their natural degree of moisture before manipulating them.

(244) *The Fixing of Stains.*

(3) An exposure to heat of 212°, whether in the form of dry heat, of boiling water, or of steam, has the effect of fixing many organic colouring matters in animal and vegetable fibre, so that they cannot be removed by subsequent washing; in fact high pressure steam is used by dyers and calico printers in an apparatus called a "keir," for the very purpose of fixing their colours. This fixing of stains is specially marked in the case of albuminous materials coagulable by heat, such as blood. It is well known that in order to remove blood stains the cloth or garment must be steeped in cold water.

The following experiments were made on this point:—Pieces of linen sheeting, marked distinctively, were steeped at one end in fresh sheep's blood, in dirty animal grease, and in claret, strips of calico were also steeped in ox-gall and in urine, and after exposure to heat the strips were washed in Messrs. Lyons's establishment in the ordinary manner with boiling water and soap and soda. The results are in the table on the following page.

This property of heat is an inconvenient one from our present point of view, and seriously limits the field for practical usefulness of disinfection by heat. It is very desirable that linen articles, sheeting, body linen, and such matters, which have been in con-

[1] *Op. cit.*

tact with infection, should be disinfected before coming into the laundry, since otherwise they may infect the washerwomen and possibly the linen of other households. Such objects however, if soiled with blood and fæcal matter, cannot be disinfected by heat, not even by boiling water, without indelibly fixing the stains. The only alternatives therefore are to put up with damage to this extent, to allow the articles to pass through the earlier processes in an undisinfected state, or to attempt their disinfection by chemical means. When the grosser dirt has been removed, by soaking and rubbing in cold or tepid water, the articles may be boiled without injury, and are then doubtless effectually disinfected.

TABLE XXXVI.

Treatment before washing.	Results after treatment and subsequent washing with soap and water.				
	Blood.	Dirty grease.	Starch.	Ox-gall.	Urine.
None	...	No stain	Brownish stain	No stain	No stain.
Soaked in cold water	No stain.	...	...	...	...
Boiled in water ½ hour	Black stiffened stain	No stain	Hardly any stain	No stain	No stain.
Steam 212° ½ hour	Do. rather darker	Hardly any stain	Brownish stain	Yellow stain	No stain.
Steam 260° ½ hour	Dark brown stiff stain.	Very slight stain	Reddish stain darker	Yellow stain	Faint brownish stain.
Dry heat 240° 4 hours	,,	Hardly any stain	Brownish stain darker than first	No stain	Brown stain like scorching.

(245) *Melting of Fusible Substances, such as Wax and Varnish.*

(4) Injury may in some instances be caused by the melting of wax and such like fusible materials in ornaments or contained in the pockets of garments. Articles occasionally catch fire when the heat of the apparatus does not exceed the normal degree, doubtless owing to lucifer matches being left in the pockets.

It is sometimes necessary to disinfect articles of furniture with stuffed seats, such as chairs and sofas. If the heat be too intense the varnished wood-work will blister, and in steam the softening of the glue will loosen the veneer.

(246) *Alterations in Colour, and Shrinking.*

(5) Dry heat short of actual scorching does not often affect the colours of dyed goods. If not properly fixed or, in technical language, "fast," steam or boiling water will cause them to run.

(6) Dry heat causes little shrinkage in woven materials. Moist heat, on the other hand, or even wetting without much heat, causes permanent shrinkage, more especially in the case of woollen goods, as cloth, flannel, and blankets. The cloth of which men's clothes are made is, "or should be," shrunk before they are made up; this shrinking is effected by exposing the cloth to steam. It will be seen however from the preceding Table that the amount of shrinkage of flannel was quite as great after simple washing as after exposure to steam. A piece of washed flannel 50 inches long (measured after washing) only shrunk $\frac{1}{4}$ inch further, or $\frac{1}{2}$ per cent., on exposure for half an hour to steam at 228°.

A more serious drawback is the felting together and loss of elasticity and fluffiness, upon which the warmth and softness of woollen materials depends. This elasticity depends upon the presence of the natural grease of the wool. M. Leblanc (quoted by Vallin) states that this grease (*suint*), which is a product of the perspiration of the sheep, is a mixture of mineral salts and organic compounds; in unwashed wool it amounts to nearly 50 per cent. of the total weight of the wool, and even in washed wool never falls below 15 per cent. This grease is of a nature highly putrescible under the combined influence of moisture and heat; so that the quantity of it contained in a mattress, together with the contaminating infiltrations from human bodies and the excrements from moth larvæ (amounting in bedding often to 1 per cent. of the whole) form collectively a very large mass of decomposing matter, which must add considerably to the contamination of the air of inhabited dwellings. On the other hand, if the wool is too well cleaned, so as to entirely remove the natural grease, it loses its strength, suppleness, and elasticity, the qualities for which it is specially valued. The suint is soluble in boiling water: water in which wool has been boiled for an hour is charged with an extremely fetid matter, rich in sulphur products; after this treatment the wool resembles cotton, it easily felts, and has permanently lost its elasticity.

These observations explain how it is that blankets will not bear boiling in water; by the removal of the grease and felting together of the wool they lose their softness and warmth, and become hard and threadbare. They may be washed in cold water or exposed to dry heat of moderate temperature without much deterioration, but a frequent repetition of these processes brings about in time a change similar to that effected by boiling water. Moreover, if wool be piled together when hot, the hairs, through the softening of the coatings of grease surrounding them, become glued together so that when cold the wool is felted into masses.

(247) *Wetting.*

(7) Wetting is undesirable in the case of some kinds of goods for it produces shrinkage and causes the colours to run and involves the labour of subsequent drying. We need only consider wetting in connection with steam. When a cool body, such as a pillow, is placed in an atmosphere of steam, some of the steam will be condensed upon it, and if the relative volume of the steam be sufficient, the temperature of the cool body will be raised to 212° F., and this temperature having been attained no further condensation of steam into water will take place. Owing, however, to the high specific and latent heat of steam, the weight of steam thus condensed will be much less than the weight of the body heated to 212° F., by its condensation.

In the experiments with Benham's apparatus, in which the steam is not superheated, the increase of weight in a pillow exposed to the action of the steam was found in two experiments to be 13 and 14 per cent. respectively, of the previous weight of the pillows. On the other hand when one of the pillows was placed under a tap and saturated with cold water, it was found to have increased in weight 140 per cent. The amount of water derived from the condensed steam was therefore only one-tenth of the quantity which the pillow would hold when saturated. A roll of flannel in the same machine increased in weight 22 per cent., a coat 36 per cent. The amount of moisture absorbed depends not only on the nature of the materials, but upon their previous state of dryness or dampness; if wet, extra heat would be required to

raise them to the temperature of the steam, and more steam would thereby be condensed.

In Lyon's apparatus, in which the steam is used at a higher temperature, being superheated by the higher degree of heat corresponding to the extra pressure on the outer case, the amount of wetting is less; in experiments with bales of rags the increase of weight varied from 3·5 to 5 per cent., the greater part of which was again lost on a few hours' exposure to air.

(248) *The different Forms of Apparatus for Disinfection by Heat.*

In Dr. Parson's paper, already so largely quoted from, he considers that the most important requisites of a disinfecting chamber are the following: (*a*) uniform distribution of heat in the interior; (*b*) a constant temperature maintained during disinfection; (*c*) facilities for ascertaining the actual temperature of the interior at any given moment.

In apparatus heated by steam, the three requirements are satisfactorily met, and in some of the best dry heat chambers the results are also fair, but in most of them condition (*a*) is not fulfilled.

As a type of a steam apparatus Lyon's will be described; as types of hot air apparatus, Bradford's, which is heated by coal, and the Nottingham self-regulating apparatus, heated by gas.

(249) *Washington Lyon's Patent Steam Disinfector.*

The machine consists of a large strong iron chamber with double walls of boiler plate, and a tightly-fitting door at either end, the door shuts against an india-rubber collar, and is secured by vice handles so as to form a steam-tight joint; it is hung on hinges and its weight when swung open is borne by a castor running on a curved rail. By means of a steam pipe, steam from a boiler can be admitted into either the hollow casing or the interior of the chamber; another pipe serves to let off the steam when no longer required, and there is also a means of escape for condensed water which may accumulate in the casing. The casing and chamber are each provided with a safety valve and pressure guage, by which the pressure of steam, and hence the temperature, can at any moment be seen,

the degrees of temperature being marked on a dial and indicated by a needle.

In using the apparatus steam is first turned on so as to heat the casing or jacket, and in this way the walls are warmed up.

The articles to be disinfected are then put into the chamber and the doors closed. It is well to allow the steam to circulate in the outer casing some time, so that the articles will become quite hot, for in this way when steam is admitted into the chamber itself, there will be little condensation or wetting. The steam is admitted ultimately into the interior of the chamber, until the gauge marks the desired temperature. On the conclusion of the disinfection, the steam is shut off from the interior, but allowed to circulate in the casing. On opening the doors, in a very little time the articles will be quite dry.

(250) *Bradford's Patent Disinfecting Apparatus.*

It essentially consists of two parts, the one a container, the other the heating apparatus. The container is a large rectangular iron box, covered with a non-conducting composition, open below and suspended by chains and counterpoises from pillars something like a gas-holder. The roof has a ventilating aperture, a thermometer is at the side, the bulb projecting into the interior, the stem being placed outside.

The heating apparatus consists of three longitudinal compartments side by side, the central one containing the fire waggon. The fuel is preferably peat, but coal, coke, or charcoal may be used; the fire is in a waggon which may be drawn in or out. The fire-chamber containing this waggon has a roof of hollow iron bars, in section triangular, open at the ends. The fire chamber has a flue at one end, a door at the other. The two side chambers are for purposes of ventilation and communicate with the fire chamber by means of side valves.

The articles to be disinfected are placed on a galvanized iron rack which stands over the fire chamber.

The container resting on a layer of sand, a large shallow vessel containing water is placed at the bottom over the fire chamber so as to keep the air of the chamber moist.

The whole apparatus may run on wheels so that it can be moved from place to place.

(251) *The Nottingham Self-Regulating Disinfecting Apparatus.*

This is the invention of Dr. Ransome, F.R.S. It consists of a cubical iron chamber cased in wood, with an intervening layer of felt, access to the interior being obtained by double doors. The furnace, placed at the side of the chamber and on a lower level, consists of a ring of atmospheric gas burners, enclosed in an iron tube. The heated air, containing the products of combustion, passes along a horizontal flue and enters the chamber at the bottom, which is perforated by a number of holes for its equable distribution. In the horizontal flue are fixed the bulbs of a thermometer and of a self-acting mercurial regulator. Through the latter the gas supply to the burners can be made to pass, and it is so constructed that as the temperature of the apparatus rises the mercury expanding encroaches upon a slit, through which the gas passes, and thus gradually cuts off the supply. At the top of the chamber there is an outlet flue, controlled by a valve and furnished with a thermometer. In connection with the outlet is an arrangement designed for the extinction of fire; when the temperature at the outlet exceeds 300° F. a link of fusible metal melts, closing a damper and shutting the supply of gas. The chamber is fitted with bars and hooks for suspending articles of clothing. When the stove is first lighted the gas is admitted to the burners direct through a short circuit pipe, without passing through the regulator, but when the mercury in the latter has risen high enough to reach the slit, this pipe is closed by a trap so as to compel the gas to pass through the regulator. The regulator is furnished with an adjusting screw, so that it can be set to work at a higher or lower temperature as required.

CHAPTER XXIV.

CHEMICAL DISINFECTANTS.

(252) *List of Practical Disinfectants.*

RESTRICTING as before the term disinfectant to a substance which is capable by its own inherent poisonous action upon a pathogenic micro-organism to destroy its life and therefore prevent its development, the list of *practical* disinfectants is a small one; all disinfectants that are expensive must be thrown out, all those which do not admit of being applied by reason of their insolubility in water, or from other causes must also be excluded, hence in this work the following disinfectants will alone be treated of at any length:—Corrosive sublimate, the halogens, iodine trichloride, the tar acids, sulphur dioxide. To this list might be added aniline on account of its remarkable disinfecting action upon the tubercle bacillus, but there is no likelihood of it becoming a disinfectant in general use. The salts of zinc, of manganese, of lead, of iron, the mineral acids, and a number of mixtures vaunted by their proprietors, may be shown generally to be of doubtful value, save in large doses, and under conditions which are only occasionally met with in practice.

(253) *Mercuric Chloride. Corrosive Sublimate. Bichloride of Mercury, $HgCl_2$.*

This well-known highly poisonous salt is in the form of a heavy crystalline powder or crystalline masses. A saturated aqueous solution contains about 10 per cent., but two parts of boiling water dissolve one part of corrosive sublimate. It is also readily soluble in alcohol or ether.

Klein[1] has studied systematically both the disinfectant and antiseptic action of perchloride of mercury when applied in the form of a solution in distilled water. Various bacteria were added to such solutions of different strengths and kept therein for a variable length of time; afterwards the vitality of the organism was tested in the usual fashion. The *modus operandi* was as follows: Into a freshly drawn out glass pipette a droplet was drawn up of the bacterial fluid, and into the same pipette the mercurial solution was drawn up in such a way that the original bacterial droplet was diluted by the mercurial solution 100 times. After leaving the bacterium and the disinfectant thus in apposition for a given time, samples of the mixture were used for inoculation of culture tubes containing solid nutritive gelatin or fluid media (generally sterile faintly alkaline broth peptone 1 per cent.) or 1 per cent. meat extract peptone. These tubes were then placed in the incubator, and the growth occurring in them if any, its character, and its differences from those of the normal organism noted.

The bacillus subtilis, in the spore state, was not killed in a less dilution than 1 per cent; the sporeless bacillus subtilis was killed in solutions of a strength of from 1 : 10,000; and from 1 : 15,000. As regards the restraining or antiseptic power of corrosive sublimate on the growth of the bacillus subtilis, it was found that one part of sublimate added to 10,000 of gelatin prevented growth. Very similar, almost identical results were obtained with *Finkler's comma bacillus* and the *comma bacillus of Koch.*

Micrococcus prodigiosis was somewhat easier killed than the foregoing, the restraining power of medicated gelatin was the same.

Anthrax.—Spores are only killed in solutions of sublimate 1 per cent. and above. Klein thus sums up the results of his numerous experiments on the antisepsis of anthrax spores:—Sublimate in nutritive gelatin in the proportion of 1 in 10,000 does not always prevent anthrax spores from germinating and producing there a crop of bacilli; but in those cases in which such amount of sublimate failed to inhibit their germination and growth, the salt had nevertheless a certain restraining influence

[1] *Supplement, Fifteenth Annual Report of the Medical Officer to the Local Government Board,* 1885, p. 155.

since the growth was retarded, was very small in amount, and its infective power was diminished, and moreover this diminution of infectivity increased with time until its total extinction was achieved. But gelatin sublimate 1 in 50,000, and in lesser proportion, has no restraining power. Sporeless bacilli are killed when treated with solutions of sublimate 1 : 2,000. One part of sublimate added to 2,000, 3,000, or 4,000 of gelatin inhibit growth *as a rule;* in solutions of sublimate of 1 : 5,000, the bacillus grows, but in some cases its infective properties are remarkably modified.

The Bacillus Septicæmia of Guinea Pigs.—Sublimate solutions of 1 : 10,000 kill both spores and threads when acting for thirty minutes. One part of sublimate in 10,000 of gelatin inhibit growth.

Tubercular virus experiments made by Lingard show that a solution of sublimate, strength 1 : 960, destroys in from four to eight hours human tubercular virus; the exposure requires to be longer in the case of bovine tubercular virus.

THE HALOGENS.

(254) *Chlorine, at. weight* 35·4, *a yellowish green Gas,* 2·4 *times heavier than Air.*

It may be prepared for the purposes of disinfection by heating together a mixture of common salt, manganese binoxide, and sulphuric acid, the following reaction occurring: $2\ NaCl + MnO_2 + 2H_2\ SO_4 = Cl_2 + Na_2\ SO_4 + MnSO_4 + 2H_2O$, or simply by the action of hydrochloric acid on manganese binoxide, $MnO_2 + 4\,HCl = MnCl_2 + Cl_2 + 2H_2O$, but both these processes are somewhat inconvenient, and it is in practice almost invariably evolved from bleaching powder by the addition of an acid.

Bleaching powder may be considered to have the formula $CaCl_2O_2 + (CaCl_2\ CaO)\ 2\,H_2O$, that is, to be a mixture of hypochlorite and oxychloride of calcium, although its composition is much disputed. Theoretically it should contain 41 per cent. of chlorine, but in practice it is seldom that more than 35 per cent. can be obtained. 1 lb. of good bleaching powder on being

treated with sufficient acid to completely decompose it, will evolve about 1·8 cubic foot of chlorine gas. To obtain anything approaching the percentages that Fischer and Proskauer found most efficacious, 2 lbs. of bleaching powder decomposed by 3 lbs. of strong hydrochloric acid will be necessary for every 1,000 cubic feet of space; this is of course on the assumption that chlorine gas will alone be used, but if as recommended at page 359 the disinfection be a combined operation, that is fumigation, heat, and afterwards mechanical processes of cleansing, then a less quantity suffices, and in practice 1 lb. of bleaching powder to 1,000 cubic feet of space will be ample.

(255) *Iodine, at. weight* 126·5, *density* 126·5.

Iodine forms rhomboidal lustrous greyish black plates. Iodine dissolves but sparingly in water, but its solubility is much increased by certain salts, *e.g.*, potassic iodide; it dissolves freely in alcohol, in ether, and in carbon disulphide. It is not well adapted for use as a fumigating agent chiefly on account of the density of its vapour which is 8·5 times heavier than air; hence it is extremely difficult to diffuse it properly.

(256) *Bromine, at. weight* 79·8, *density* 79·8.

Bromine is a dark red liquid of an exceedingly irritating odour. It is soluble in water, a saturated solution containing about 3 per cent. at ordinary temperatures. A method of using it as a fumigating agent is given at page 344.

(257) *The Experiments of Cash on the Halogens.*

The most important experimental determination of the value of the halogens has been made by Dr. Cash, F.R.S. (*Supplement to the Sixteenth Annual Report to the Local Government Board.*) The object of the inquiry was to determine the lethal limits of chlorine, iodine, and bromine, as well as sulphurous acid, to anthrax, to human and bovine tuberculosis.

Dr. Cash thus describes the methods he adopted :—

With the object of rendering the investigation as precise as possible, I have when testing the effect of solutions of these

halogens, employed graduated strengths which could be readily controlled by means of occasional standardizing.

Water solutions of chlorine lose strength with more or less rapidity, solutions of sulphurous acid rapidly, a partial conversion into sulphuric acid as a result of oxidation taking place. Bromine in solution is moderately stable, and iodine practically perfectly so.

Using a solution of iodine of known strength as the starting point for the standardizing of the other solutions, and taking of it an $\frac{n}{10}$ solution (*i.e.* 12·653 grms. of iodine per 1,000 c.c. distilled water, or 1·27 per cent), it is easy to satisfy ourselves that an equal volume of standard hyposulphite solution discharges the colour of the iodine, starch being used as the indicator. The hyposulphite being found up to strength, the standardizing of the chlorine and bromine solutions is effected by estimating their power of liberating iodine from iodide of potassium, starch as before being used as indicator.

Koch places the solutions of the halogens which arrest the development of anthrax bacillus as follows :—

Iodine 1 : 5,000, Bromine 1 : 1,500, Chlorine 1 : 1,500.

He farther found that spores of anthrax were destroyed in iodine (1 : 7,000) one day ; bromine (two per cent) one to five days ; chlorine (freshly made) one to five days. The original solutions employed were of iodine $\frac{n}{10}$, of bromine $\frac{n}{20}$, of chlorine $\frac{n}{20}$. From these more dilute solutions were made by careful measurement and controlled by standardization the $\frac{n}{100}$ solutions having the following values :—iodine 1·27 grms. in 1,000 c.c. of water : chlorine ·3537 in 1,000 c.c. water ; bromine ·7975 in 1,000 c.c. water.

The real question at issue is not merely the action of a certain solution having a given percentage strength, but the action of such a fraction, say of a cubic centimetre containing a known quantity of the disinfectant upon a given quantity of blood or cultivating medium within which the particular micro-organism is present.

Supposing, for instance, that we expose one twentieth of a drop of anthrax blood to the action of iodine, we obtain no definite notion of its disinfecting power by stating that the latter was present in the proportion of one per cent. in the solution unless we know farther the actual quantity of the solution available for action upon the micro-organisms. By exposure in a hermetically

sealed bulbous pipette the strength of the solution is well insured during its action, its complete mixture having been accomplished beforehand in a watch glass.

Supposing, to complete the example, that 1 c.c. of $\frac{n}{100}$ iodine solution is mixed with one twentieth drop of anthrax blood, we then have as iodine actually present, in 1 c.c. ·00127 and one tenth c.c. = ·000127 grm. We can state therefore that this quantity of iodine acting for five minutes upon one twentieth drop of anthrax blood destroys the contained bacilli, in other words thoroughly disinfects it in a given time.

The experiments hitherto made with the haloid bodies and sulphurous acid are in so far double, as they test the disinfectant action of these bodies in solution and as vapours passed through a solution containing the micro-organism to be disinfected.

In the end it is true that the effect is—as the menstruum becomes more and more highly charged with gas which is dissolved in it—in both cases that of the exposure of a cultivation of whatever the microbe may be to a disinfectant solution; but it is in the first instance a matter of considerable interest and utility to determine how far the passage of gas through an infusion of some pathogene will destroy its life, when, by reason of the speed of its transmission probably not all but a part only of the gas acts directly upon it. It is in the first instance less a question of the action of a saturated fluid than it is of the affinity of the passing gas, so to speak, for the microbe with which it is in conflict. Even at very low speeds of delivery of air charged with disinfectant vapour, of say, 12 to 20 bubbles per minute, it is found that from the first a certain amount of gas, be it chlorine, bromine, or SO_2, passes through the infusion of the pathogene and discharges iodine on the distal side from an iodide of potassium solution. If, on the other hand, a substance such as KI, upon which the generated gas acts chemically, liberating iodine, be substituted for the pathogenic infusion so that we have two vessels containing KI solution in series, we find that a very rapid discharge of the gas is necessary to decolourize the solution situated distally; not until all the KI is decomposed in the vessel into which the gas first passes, does the farther vessel begin to show decolourization likewise.

Experiments were made with solutions of the halogens and also on infusions of virus traversed by the gas.

"The general method followed when solutions were employed was to take for example 1 part of the blood of an animal just dead from anthrax, to mix it with 49 parts of the standard chlorine water, or a dilution of it, mix in a watch glass, draw it up in a pipette, seal the pipette for a definite time, at the end of which the end of the pipette was broken off and an animal inoculated. In this way it was found that ·00035 grm. chlorine disinfected in five minutes one fiftieth of its bulk anthrax blood, but that a dilution to one half was not certain in its action. The blood from an animal dying of anthrax is always spore free, so that this statement only applies to the bacilli. With regard to anthrax spores it was found that chlorine solution of $\frac{n}{20}$, mixed in the proportion of 20 to 1 of a strong solution of anthrax spores, destroyed them within 24 hours. With regard to tubercular material, one twentieth of a drop of strong infusion of a tuberculous spleen, mixed with one drop of $\frac{n}{100}$ chlorine solution kept in a pipette respectively for 1 hour and for 24 hours, did not disinfect within the shorter time but did in the longer time : the quantity of chlorine in this case was ·000035 grm. In another experiment in which a similar dosing took place, and it was submitted to the action of a disinfectant for 28 hours, the result was not so good, for the inoculated animal died from tuberculosis. Using a strong solution of a tubercular lung, Cash found that 4 minims of a chlorine solution containing ·0008 grm. of chlorine destroyed the virus in one drop of such infusion within one hour and a half.

"In the second method, air from a gas-holder was passed slowly through strong chlorine solution and thus charged with the gas passed through nitrogen bulbs containing a solution of the pathogenic substance to be acted upon. From time to time, usually at the beginning and end of an experiment, this bulb was replaced by another, which contained fresh acidulated solution of iodide of potassium, in order that the amount of escaping gas might be estimated for a given time by the liberation of iodine as calculated by subsequent titration with a standard hyposulphite solution."

One point Dr. Cash endeavoured to obtain information on, viz. —"If a stream of air laden with a certain ascertained amount of disinfectant gas be passed with a given speed through a solution containing pathogenic micro-organisms, how soon will the disinfectant's action make itself felt as evidenced in the destruction

of such pathogenes? If we bring two nitrogen bulbs containing iodide of potassium into connexion distally with a bottle containing chlorine solution through which air is slowly forced to them from a Pepy's gas-holder, we observe that in the bulb nearer to the gas supply the iodide of potassium is rapidly decomposed, iodine being set free, but in the second bulb no decomposition whatever occurs, at any rate for a considerable time, the fluid remaining perfectly colourless.

"If now we substitute for the proximal bulb another containing say, an infusion of tubercular lung, and continue the circulation of air charged with chlorine through this and through the distal KI bulb, we notice almost immediately a liberation of iodine in the latter; this simple experiment shows us that an escape of the gaseous disinfectant takes place before its maximal action has been attained (as demonstrated by experiment), the maximal action for our purpose being death of all micro-organisms, coagulation of albuminous bodies, and other actions. Whilst in its passage through the bulb a portion of the chlorine acts on the contents causing certain effects by liberation of oxygen, a portion remains behind in general solution having a potentiality for further action, and still another portion passes away without having produced any disinfectant action. Small portions of the nascent oxygen are probably lost in the same manner."

The following are the details of an experiment by Dr. Cash:— "Took one tubercular lung of a guinea-pig killed when suffering from human tuberculosis. The lung was studded with translucent pearls, the spleen enlarged, and the liver slightly necrotic. The lung was broken up in a mortar with a little distilled water, the fluid strained through muslin, diluted up to 10 c.c. and transferred to a nitrogen bulb.

"Air was passed slowly (10 bubbles per minute) from a Pepy's gas-holder through a bottle with the proximal tube dipping beneath the surface of a considerable volume of chlorine solution.

"The second tube communicated by means of an air-tight joint with the nitrogen bulb. The chlorine coming over was determined by means of liberations of iodine from a slightly acidulated KI solution. 0 min., circulation commenced through the nitrogen bulb containing tubercular material. 10 min., infusion has changed much in colour, is now of turbid appearance, deep brownish red. A

sample was taken and at once inoculated into a guinea-pig. The circulation of the gas was interrupted only for a few seconds and was then continued for 40 minutes more without stoppage. At the expiration of this time the infusion was of a deep muddy brown colour. A second guinea-pig was then inoculated. The total chlorine passed through the solution as estimated by the discharge of colour from the liberated iodine by sodic hypo-sulphite solution was before the first inoculation ·016 grm.; before the second, ·064 grm. (·064 + ·016 = ·08 grm.).

"In spite of this relatively large discharge of chlorine both animals became tubercular, and when killed the usual appearances were found in their organs.

"In the next two experiments the tubercular virus was successfully destroyed.

"The lung employed was that of a guinea-pig suffering from human tuberculosis, and the preparation of its infusion was the same as in the last experiment.

"A variation was, however, made in this experiment by generating larger quantities of chlorine from hydrochloric acid and manganese dioxide under gentle heat and conducting the gas through a small wash bottle originally containing water, before leading it through the nitrogen bulb.

"A control animal was inoculated with the lung infusion before the circulation of the disinfectant was commenced. An estimation of the escaping gas was made as before, and then the nitrogen bulb with its contained infusion was put into connexion with the second bottle.

"Inoculations were made after the passage of air laden with chlorine at the rate of 16 bubbles per minute, for (*a*) 2 minutes, for (*b*) 6 minutes, and for (*c*) 10 minutes, respectively. The issuing chlorine was again estimated at the end of the experiment.

"It was calculated that before the first inoculation ·0710 grm. of chlorine had been passed. In all before the second (*b*) ·213 grm. In all before the third (*c*) not more than ·335 grm. But a the third estimation of chlorine showed a slight falling off in the evolution of the gas, the total may have been somewhat less.

"The control guinea-pig and the guinea-pig (*a*) became distinctly tubercular (though some delay in the development of glandular swelling appeared to occur in the latter). The other two (*b*) and

(*c*) guinea-pigs escaped infection altogether. There is only one conclusion to be drawn from this experiment, namely, that air strongly laden with chlorine gas can rapidly disinfect or destroy a great mass of tubercular virus by transmission through a solution of the latter.

"In a third experiment an infusion of a tubercular lung was disinfected in 4 minutes, the quantity of chlorine being about ·05 grm., and in another, ·0355 grm. acting for 2 minutes failed to disinfect, but ·0768 acting for 6 minutes disinfected."

Very similar experiments were made with iodine and bromine, the general result being to show that there was no very decided difference between the three, but that in order of disinfecting power when employed in quantities proportional to their atomic weight, iodine was the best, next bromine, and last chlorine.

The value of chlorine as a disinfectant has been strikingly shown by Klein (*Thirteenth Annual Report Loc. Gov. Board, Supplement*). Klein's experiments were made on swine plague, a disease easily reproduced and highly infectious, for he had already proved (1877–78) that the infection spread from a diseased to a healthy animal living in the same stable with it, this even when the animals were separated by considerable space; and if a diseased and healthy animal were placed in the same building in two different compartments, but both compartments opened into each other, the healthy animal contracted the malady. He found that if the air of the stable was kept pungent with chlorine, healthy and diseased animals might occupy adjoining compartments and also that one good fumigation of a stable infected from animals which had died of the swine fever, was effective.

(258) *The Experiments of Fischer and Proskauer.*

Fischer and Proskauer[1] made some very important researches on the disinfectant action of chlorine and bromine. The substances submitted were sometimes in a large glass vessel of 21·35 litres capacity, and sometimes placed in a cellar which was made into an experimental room. The gas was developed from binoxide of manganese and hydrochloric acid. In some of the experiments

[1] *Mittheilungen aus dem Kaiserlichen Gesundheitsamte.* Bd. ii. Berlin, 1884.

the air was specially dried by means of strong sulphuric acid, in others the air was saturated with moisture.

The pathogenic substances submitted for disinfection were :—

(1) Spore-holding micro-organisms such as anthrax in the spore state, the so-called earth bacillus, and dried tuberculous sputum.

(2) Spore free micro-organisms such as the bacillus anthracis (spore free), the microbe producing septicæmia in mice and rabbits, fowl-cholera, yeast, sarcinæ, and several others.

The results were tested mainly by ascertaining how far the disinfected bacteria were capable of growing on nutrient soil, but in a few cases inoculation of animals was resorted to. The original paper must be referred to for full details, but the chief results were as follows :—

No less percentage than 5·38 chlorine per 1,000 of air in rooms to be disinfected can be considered efficacious.

It is best to keep the air of the room moist for some time before disinfection.

Disinfection in dry air is uncertain.

Chlorine fumigation carried out under the best conditions may fail to disinfect spore-holding material covered over or lurking in chinks and cracks.

In all cases chlorine is far more efficacious than sulphurous acid gas.

In their experiments on the disinfecting power of bromine, they used for the purpose of developing bromine vapour the ingenious process of Dr. Frank—fluid bromine is made to soak into a porous siliceous earth, the earth is preserved in well stoppered bottles ready for use; on removing the stopper the heavy bromine vapour pours over the neck of the bottle and gradually diffuses itself about the room; the bottle should of course be placed as near the ceiling as possible. This process is far above all others in the single point of ease of application.

They found that provided the air of the room was sufficiently moist a good superficial disinfection could be attained with bromine but even with such high quantities as 35·7 grms. of bromine per cubic metre of air, spore-holding anthrax escaped disinfection. They also found that bromine was more destructive of organic tissues such as cotton or woollen goods than chlorine; these disadvantages and the higher price led them to give the preference to chlorine.

(259) *Iodine Trichloride*, ICl_3.

Iodine trichloride is in the form of orange-yellow needles. It is formed by heating iodine pentoxide (*iodic anhydride*) in hydric chloride. The iodine pentoxide liquefies, and is converted into iodine trichloride according to the following equation:—

$$I_2O_5 + 10\,HCl = 2\,ICl_3 + 5\,H_2O + 2\,Cl_2.$$

The crystals are soluble in water; the solution has no action on starch.

Iodine trichloride will probably be an important disinfectant, its power having been carefully determined by Dr. Otto Reidel. The following is an abstract of his research[1]:—

Threads infected with anthrax spores were steeped in 1 per cent. and 1 per 1,000 solutions of ICl_3 for 24 and 48 hours. In all these cases there was complete disinfection, as proved by cultivation and also experiments on animals. Hay bacillus spores, experimented with in the same way, but using a 1 per cent. solution, were not disinfected in $8\frac{1}{2}$ hours, in 12 hours were imperfectly disinfected, in 24 were completely disinfected. Garden earth spores were disinfected in 19 hours with the same solution. Anthrax threads, containing no spores (because derived from the blood of an animal dying from anthrax), were completely disinfected in 2 hours by a 1 per cent. solution, and it was shown by experiment that this strength in activity was about equal to a 3 per cent. solution of phenol. A similar result was obtained in experiments with the Staphylococcus aureus, and the Staphylococcus derived from osteo-myelitis, a 3 per cent. solution of phenol and a 1 per cent. solution of ICl_3 acted effectually in equal times, the former, S. aureus, being killed in 14 minutes, the S. osteo-myelitis in 60 minutes. The cholera comma bacillus was killed in 1 minute by 5 per cent. solution ICl_3; in 3 minutes by phenol of the same strength. Experiments were also made on the effect of small quantities of ICl_3 added to the nutrient material serving as a soil for the cultivations. It was found that so little as 1 : 3,000 prevented the growth of a variety of pathogenic

[1] *Arbeit aus dem Kaiserlichen Gesundheitsamte*, 2 *Band*, 1887.

organisms, such as the micrococcus from erysipelas, the streptococcus pyogenes, the anthrax bacillus, and the cholera bacillus; but others required the proportion of ICl_3 to be in the nutrient gelatin as 1 : 850, and the bacillus derived from typhoid excreta resisted in even 1 : 500. This latter property of the typhoid bacillus has been utilized by Chantemesse and Widal to raise it from typhoid excreta (*Gaz. Hebd. de Med. et de Chir.*, 1887, No. 9, 146). A practical test of its use to the surgeon was made by placing the hands in a putrid liquid, washing them in the ordinary way, then rinsing with a 1 per cent. solution of ICl_3, getting rid of the disinfectant by washing it off with sterilized water, finally submitting scrapings of the skin of the hands to cultivation; no growth followed. Lastly, the author compares the poisonous properties of ICl_3 weight for weight with $HgCl_2$ (corrosive sublimate) and phenol. These experiments were all made on rabbits, the poisons being administered by peritoneal and subcutaneous injection. ICl_3 in 1 per cent. solution, injected into a rabbit in the proportion of ·45 grm. per 10 grms. of rabbit, had neither local nor general effect, but the same relative quantity in 10 per cent. solution caused local necrosis. The animals mostly lived; one died after 10 days. Other experiments showed that a fatal dose for a rabbit was somewhere near 9 grms.; while a subcutaneous injection of a 1 per cent. solution of corrosive sublimate killed ·15 per 10 grms. of rabbit, and in a greater dilution of 1 per 1000. ·32 per 10 grms. killed. Phenol was fatal when injected subcutaneously in the proportion of 3·48 per 10 grms. of rabbit.

(260) *Phenol. Carbolic Acid.*

Phenol. C_6H_5HO. When pure and absolute, phenol is in the form of white crystals; the crystals melt at 42·2° (108° F.). Boiling point, without decomposition, = 182° C. Water gradually added to phenol, so long as it dissolves, gives a liquid hydrate of the composition $C_6H_6O2H_2O$, equal to 27·7 per cent. of water. The solubility of the crystals in water is very nearly that of 1 in 11; a saturated solution in water will contain about 8·6 per cent. of phenol. It is far more soluble in weak alkaline solutions than in water. It is (when absolute) soluble in all proportions in alcohol, ether, benzine, carbon disulphide, and chloroform.

(261) *Cresol. Cresylic Acid,* C_7H_7HO.

Cresol is known in three forms—meta-, para-, and ortho-cresol. Para- and ortho-cresol are respectively obtained by fusing the pure potassic salts of the two isomeric sulphonic acids produced on heating toluene with sulphuric acid with potassic hydrate. The three modifications are not in ordinary commerce. Specimens the author obtained from Kählbaum had the following general appearance and properties:—Meta- and para-cresol were both liquid, of a reddish colour: para-cresol had a most unpleasant odour; meta-cresol had the smell of ordinary cresol; ortho-cresol was in the form of needle-like crystals, odour pleasant and aromatic.

The commercial cresol, which makes up the bulk of the cheaper fluid so-called carbolic acid, is of a red colour, and contains meta- and para-cresol, with perhaps some small quantity of ortho-cresol; the boiling point varies from 198° to 200° C. It is less soluble than phenol; a saturated aqueous solution will contain about 3·3 per cent. It is soluble in weak alkaline liquids, but is precipitated with excess of alkali.

(262) *Estimation of Impurities in Commercial Carbolic Acid.*

The chief impurities of the dark liquid carbolic acid of commerce are tar oils; their presence is ascertained, and their quantity approximatively estimated, by shaking a measured volume of the acid with twice its volume of pure soda solution of 9 per cent. strength. The cresylic and carbolic acids are dissolved by the alkaline liquid, while the oils separate—"heavy oils" sinking to the bottom, "light oils" rising to the top; the volume in either case can be read off. These tar oils have not been shown to possess any disinfectant properties. If it is required to ascertain the relative mixtures of cresylic and carbolic acids, this is best done by a fractional distillation, collecting the various products and carefully measuring them. A process for this purpose has been given by Mr. Lowe, and has been quoted by Allen; the process is as follows:—

100 c.c. of the sample are placed in a retort and distilled into a graduated vessel. The first 10 c.c. of the distillate contains water and oil; the volume of each is determined, and the receiver

changed. The next portion should consist of anhydrous acid, and when the distillate amounts to 62·5 c.c., the receiver is removed and the distillation stopped. The residue in the retort consists wholly of cresylic acid and the higher homologues of cresylic acid. To ascertain the relative proportions of cresol to phenol in the 62·5 c.c., it is necessary to carefully ascertain the solidifying point which should be between 15·5° and 24° C., then imitation mixtures of phenol and cresol are made until a known mixture is obtained with the same solidifying point, or of course the reverse process may be used, *i.e.*, the liquefying point determined.

(263) *Carbolic Acid Powders are Powders which should contain Free Tar Acids.*

All carbolic acid powders that have for their basis lime, and are hence mixtures of carbolate and cresylate of lime, are absolutely useless, exerting no appreciable disinfecting properties. A good carbolic acid powder is that which is merely a mechanical mixture of the acid and the powder, as for example "Calvert's carbolic acid powder," which is made by adding carbolic acid to the siliceous residue resulting from the manufacture of aluminium sulphate from shale. Macdougall's disinfecting powder is also to be mentioned with approval; it is made by adding a certain proportion of crude carbolic acid to an impure sulphite of calcium prepared from the action of sulphur dioxide on ignited limestone.

Carbolic Acid Soaps are soaps containing more or less free carbolic acid; it is doubtful whether they are of the slightest use for disinfecting purposes or are at all superior to ordinary soap. Trustworthy and impartial experiments of a strictly comparative character have however not yet been made as to this.

(264) *The Author's Experiments on the Disinfecting Powers of Phenol and Cresol.*

The author has made many experiments on the relative disinfectant powers of pure phenol, and the purest commercial samples of cresol obtainable (this is as stated a mixture of ortho-, para-, and meta-cresol) and with pure samples obtained from Kahlbaum of ortho-, meta-, and para-cresol.. Some of these experiments have been already published, others appear here for the first time.

EXPERIMENTS ON THE DISINFECTION OF THE BACTERIUM TERMO.

Phenol and Cresol.—These experiments were made by the "drop" method.

Weighed quantities of pure crystalline phenol and of pure liquid cresol were dissolved in 20 per cent. alcohol in such proportion that the strength was exactly 1 per cent. Water which had been infected with the bacterium was measured from a burette into test-tubes, and definite quantities of the phenol or cresol solutions added; the volume of the whole being kept at 10 c.c., *e.g.*, 3 c.c. of phenol solution, and 7 c.c. of the infected water would equal 0·3 per cent., 1 c.c. of phenol solution and 9 of the infected water would equal 0·1 per cent., and so on. At the end of twenty-four hours nutrient gelatin was infected by means of dipping a clean recently ignited platinum wire in the liquid, and then inserting the wire for a second or two in the gelatin, which had been previously liquefied. The following short table summarizes these experiments; the – sign denotes no growth, the + sign denotes the first appearance of evident growth and liquefaction.

TABLE XXXVII.

PHENOL AND CRESOL.

Days	2.	3.	4.	5.	6.	7.	8.	9.	10.
At 15·5° C.—									
Phenol 0·01 per cent.	—	—	—	—	+				
,, 0·01 ,, ...	—	—	—	—	+				
,, 0·10 ,, ...	—	—	—	—	+				
,, 0·25 ,, ...	—	—	—	—	+				
,, 0·50 ,, ...	—	—	—	—	—	—	—	—	—
Cresol 0·01 ,, ...	—	—	—	—	+				
,, 0·05 ,, ...	—	—	—	—	+				
,, 0·10 ,, ...	—	—	—	—	+				
,, 0·25 ,, ...	—	—	—	—	—	—	—	—	—
,, 0·50 ,, ...	—	—	—	—	—	—	—	—	—
Control	+								
At 35·5° C.—									
Phenol 0·01 per cent.	—	—	—	+					
,, 0·05 ,, ...	—	—	—	—	+				
,, 0·10 ,, ...	—	—	—	—	—	+			
,, 0·25 ,, ...	—	—	—	—	—	—	—	—	—
Cresol 0·01 ,, ...	—	—	—	+					
,, 0·05 ,, ...	—	—	—	—	+				
,, 0·10 ,, ...	—	—	—	—	—	—	+		
,, 0·25 ,, ...	—	—	—	—	—	—	—	—	

From which it may be concluded that at ordinary temperatures commercial cresol disinfected the *bacterium termo* in somewhat less dosage than phenol, 10 per cent. cresol being equal to 50 per cent. phenol; at higher temperatures the action was equal.

(265) *Experiments on the Disinfectant Action of Phenol and the Cresols on Sewage.*

The phenol was absolute crystalline phenol, the cresols were obtained from Kählbaum; 1 per cent. solutions were used, but the volumes added to the sewage were proportional to the molecular weights of phenol and cresol. Equal quantities of sewage were placed in test tubes; to some of the tubes 4·7 c.c. of the 1 per cent. solution of phenol were added, into others 5·4 c.c. of the cresols; these reacted for twenty-four hours, the disinfected solutions were then made up by the aid of sterilized water, with suitable precautions, to a definite bulk of which weighed drops were taken and cultivated in the manner detailed at p. 315. It may be necessary to observe that the quantities of disinfectants being mutually equivalent, the relation of the weights was 36 cresol to 30 phenol.

On the eleventh day the colonies were counted:

	Mean number of colonies per 100 mgms. sewage.		Mean number of colonies per 100 mgms. sewage.
Ortho-cresol	99	Meta-cresol	146
Phenol	136	Para-cresol	170

From which it may be deduced that ortho-cresol is a little superior to phenol and the other cresols, and that the disinfecting action of phenol and meta-cresol is pretty well equal.[1] Experiments were also made as to the relative power of these substances to destroy the odour of highly offensive sewage. The sewage was diluted, and a sufficient quantity of the disinfectant added so that the strength was equal to ·5 per cent. The mixture was allowed to stand for about an hour. The disinfected sewage was then slightly warmed, sucked up and down a wide tube, and the lower end of the tube being still in the flask just above the liquid, the nostril was applied to the upper end of the tube, and the vapour sniffed up. The results were:

Phenol . . . A very faint urinous odour.	Meta-cresol . . . Feeble aromatic odour.
Ortho-cresol . Aromatic odour.	Para-cresol . . . Decided urinous odour.

[1] On the other hand, Carnelley and Frew find that with regard to the di-derivatives of benzene, the para-compounds are more antiseptic than the ortho- and meta-compounds. *Journ. Chem. Soc.*, 1890. *Chemical News*, June 13, 1890.

There is no doubt of the superiority of ortho-cresol over any of the others; the more especially when it is considered that the odour is unmistakably agreeable. Unfortunately ortho-cresol is at present only a scientific curiosity and of a high price. In practice there is no real difference in the action between pure phenol and the so-called carbolic acid of commerce, provided equal strengths be compared; the crude dark coloured 90 per cent. carbolic acid used extensively by local bodies mostly contains large quantities of cresol, and only small quantities of phenol, the manufacturer having as far as possible separated all crystalline materials, but as it has been shown that cresol is a little superior to phenol, and the price is very much less, it is folly to use the dearer article for disinfecting purposes on a large scale.

(266) *Koch's Experiments on Phenol.*

Koch has made many experiments on the effect of phenol on anthrax. He found that a couple of minutes steeping of threads contaminated by *spore-free* anthrax in a 1 per cent. aqueous solution of phenol, was sufficient to destroy the bacilli; on the other hand spore anthrax was not killed save by prolonged contact with much stronger solutions; *e.g.*, an aqueous 3 per cent. solution acting for five days failed to disinfect; 4 per cent. succeeded in destroying the spores after three days, and 5 per cent. after two days. He found that carbolic acid dissolved in oil or strong alcohol had no disinfecting power, and that of the phenol salts, a 5 per cent. solution of sulfo-carbolate of zinc was capable of destroying anthrax spores if the latter were soaked in the solution for five days, but sodium-phenol as well as sodium sulfo-carbolate had little effect.

(267) *Schill and Fischer on the Action of Phenol on Tuberculous Matters.*

Schill and Fischer in their elaborate investigation on the disinfection of tuberculous matters, by various disinfectants, found that fresh sputa still produced tuberculosis when injected into animals after being treated for twenty hours with solutions of phenol from 1 up to 3 per cent., a 5 per cent. solution acting for two hours failed to disinfect, but acting for twenty-four hours was invariably successful. On the other hand, if an

antiseptic action only is desired, there are plenty of observations to show that traces of phenol inhibit the growth of a large number of micro-organisms.

(268) *Summary of the Action of Phenol and Cresols as Disinfectants.*

Phenol and the cresols hold a high position as disinfectants: a 1 per cent. solution is strong enough to destroy the more feeble infections, but to be certain that the more resistant forms of germ life are annihilated it will be necessary to use at least 5 per cent. solutions in water, and the action must be prolonged; if specific excreta are treated it is doubtful whether 5 per cent. solutions are of sufficient strength, because associated with the hurtful material there is a quantity of organic matter which must on the one hand remove some of the phenol from the sphere of action, and on the other impede the contact of the phenol with the substances which we wish to disinfect.

(269) *Creasote.*

Wood tar creasote is a mixture of several phenol-like bodies, the chief of which are guiacal, or oxycresol, $C_7H_8O_2$, boiling point 200°-210°, and creasol, $C_9H_{12}O_2$, boiling point 217°.

The considerable insolubility in water of creasote is a bar to its extensive use as a disinfectant. It is otherwise probably about equal to cresol, but few experiments of an exact kind, made in the modern way have been hitherto published, besides which, the uncertain composition of commercial creasotes renders any but a general statement impossible. Its powerful antiseptic properties, as for instance in the preservation of timber, are well known.

(270) *Phenyl-propionic and Phenyl-acetic Acids.*

Phenyl-propionic and Phenyl-acetic acids have been investigated by Klein (*Thirteenth Annual Report to the Local Government Board, Supplement*). He found that as regards spore-free bacillus anthracis, the bacilli were certainly killed on exposure, even for a few minutes, to solutions of either of the acids in the strength of 1 : 400 or less; with regard to greater dilutions a longer time was necessary, and phenyl-acetic proved to be a little weaker than phenyl-propionic. These aromatic acids were also efficacious in destroying the virus of swine plague, when the strength was not

less than 1 : 800, but experiments on tubercle bacillus, even with strong solutions, produced no very appreciable effect.

Mr. G. F. Dowdeswell (*op. cit.* p. 193), while recognising both these acids as powerfully antiseptic, did not find in experiments on *symptomatic charbon* that they had any constant or determinate action on the virus.

(271) *Sulphur Dioxide (Sulphurous Acid Gas)*, SO_2.

This gas is formed whenever sulphur is burnt in air or oxygen. Its molecular weight is 64, vol. weight 32, sp. gr. 2,217. Its composition by weight is equal parts of sulphur and oxygen; its composition by volume is 1 volume of sulphur, and 2 volumes of oxygen condensed into two.

Sulphurous acid, or more accurately sulphur dioxide, is in its concentrated form an irrespirable gas, and even when dilute causes considerable laryngeal irritation; it bleaches many organic colours, and reddens litmus.

It is injurious to vegetation, and when present in the atmosphere in but minute quantity some plants are affected by it.

It is the most common acid in the air of towns, being derived from the burning of sulphur contained in the coal.

Sulphur dioxide may be condensed to a liquid by the application of cold or pressure, or both combined. The pure liquid anhydride is a thin blue liquid of sp. gr. 1·491, and is an article of commerce, and may be bought in quantity, but the liquefied anhydride may be dangerous if trusted to unskilled hands.

Sulphur dioxide has been for a long time the most common and favourite disinfecting agent, by reason of its cheapness, and the ease with which it can be generated. The usual way has been to take about a pound of roll sulphur, seal up a room as hermetically as possible, light the sulphur in some proper receptacle, and let it burn as long as it will. Or, a still more convenient method is to take an ordinary benzoline lamp, charge it with carbon bisulphide and light; as the carbon bisulphide is consumed the sulphur is emanated as sulphur dioxide.[1] Seabury's sulphur candles are also

[1] Ckiand Bey's lamp is used in some of the continental hospitals for the purpose of burning safely CS_2. It is very ingenious, and is so arranged that as the volatile liquid sulphide burns away water takes its place; finally, when all is burned, the water rises to a level with the wick. It is described and figured in Dujardin Dumetz's *L'Hygiène Prophylactique.* Paris, 1889.

convenient; they consist of a cake of sulphur, in the centre of which are two or three wicks, saturated with nitre; the wicks light easily, and the whole cake burns gradually away.

It is however doubtful whether sulphur dioxide will retain its place as a disinfectant; for although there are remarkable discrepancies as to the results obtained by different experimenters, the impression remains that it is an uncertain agent.

When sulphur is burnt in a perfectly close space, its consumption is limited by the quantity of air in that space: theoretically a cubic foot of air will burn up 624 grains of sulphur, but it will not do this unless copiously supplied with air.

The best results are obtained in imperfectly ventilated places by well moistening the sulphur with methylated spirit; under the best conditions the air of the room thus disinfected may contain 10 per cent of SO_2.

(272) *Wolffhugel's Researches on the Disinfecting Properties of Sulphurous Acid Gas.*

Gustav Wolffhugel[1] has made the most elaborate research on the value of sulphur dioxide as a disinfectant. The following is a brief abstract of his research. With the addition of alcohol under strict experimental conditions, 40 per cent. of the possible total quantity of sulphur in a closed space can be burnt, and in rooms the volume percentage may reach 10 per cent. To attain the maximum amount the sulphur must be broken up into pieces not larger than a hazel nut, and divided about a room, never putting more than a pound in one vessel.

Experiments were made on loss of SO_2 during the process of disinfection in rooms, this was found to range from 38 to over 90 per cent of the gas developed. The causes of loss being leakage, oxidation to sulphuric acid, precipitation with water, and absorption by porous substances (this latter can of course hardly be called waste in a disinfecting point of view). In some of the experiments the walls were moistened with water, but the results obtained were not encouraging, the volume of free SO_2 in the air being notably diminished. The diffusion of SO_2 evolved in a room was found to be fairly equal, samples of air taken from different

[1] *Mittheilungen aus dem Kaiserlichen Gesundheitsamte.* Bd. i. 1881.

heights showing unimportant deviations. Experiments were also made as to the power of penetration into plaster, but this was found most irregular. The following table gives results of experiments made with lime paste exposed on glass plates:—

TABLE XXXVIII.

Volume of SO_2 in the experimental room.	Duration of experiment. Hours.	SO_2 absorbed (mgrms.).
3·1	21	371·5
3·1	21	486·5
2·6	5	66·7
2·6	5	323·2
2·5	5	145·0
2·5	5	216·0

Of greater interest is the determinations of amounts of SO_2. absorbed by square metres of cloth exposed to the gas.

TABLE XXXIX.

Duration of experiment (hours).	SO_2 Vol. %	Material.	Surface exposed Square metres.	Thickness. mm.	Number of threads per square centimetre.	Permeability.	SO_2 absorbed (mgrms.)
		Dry and clean.					
5	2·5	Linen shirting	1·3	·25	36 : 36	2·28	4·0
		Cotton Stuff	1·3	·80	26 : 19	2·18	7·8
		Flannel	1·3	1·00	28 : 28	2·40	28·5
		Dry but dirty.					
		Linen shirting	1·3	·25	36 : 36	2·28	3·5
		Cotton stuff	1·3	·80	26 : 19	2·18	3·5
		Flannel	1·3	1·00	28 : 28	2·40	24·6
		Moist and clean.					
5	4·6	Linen shirting	1·3	·25	36 : 36	2·28	6·1
		Cotton stuff	1·3	·80	26 : 19	2·18	11·6
		Flannel	1·3	1·00	28 : 28	2·40	58·7
		Moist and dirty.					
		Linen shirting	1·3	·25	36 : 36	2·28	5·7
		Cotton stuff	1·3	·80	26 : 19	2·18	8·9
		Flannel	1·3	1·00	28 : 28	2·40	38·7

From these experiments it may be generally gathered that clean things absorb more SO_2 than dirty, and that moist things absorb more than dry. As might be expected, flannel absorbs more than linen or cotton, and of the latter two, linen is the least absorbent.

The applicability of SO_2 as a general disinfectant for goods in transit was tested in the following manner:—

Two overcoats, a bundle of linen, a bundle of wadding, three envelopes of various thickness, a roll of dark green flannel, and a mass of tow pressed in a cubical shape, the side of which was 70 cm., were exposed to the gas in a room, the volume of the gas being 1 per cent. Litmus paper was placed in suitable positions within these different articles. The duration of the experiment was 24 hours. The gas penetrated through all the articles save through the cubical mass of tow, but a second experiment, in which the amount of the gas was raised to 10 per cent. of the air, was more successful, complete penetration of the tow being effected. This result would, however, not be obtained in practice; therefore Wolfhugel condemns the use of SO_2 on a large scale for the disinfection of goods in transit.

Wolfhugel next turned his attention to the question of the injurious action of SO_2 on clothing, iron, and other objects. 1 per cent. of SO_2, acting for many hours, attacked bright metal objects so slightly that the film deposited was easily rubbed off; woollen fabrics were also not injured. When the percentage volume of the gas was raised to 10 per cent., acting for 24 hours, two overcoats and a roll of flannel exposed were changed to a red colour. Washing with ammonia water imperfectly restored the colour.

Wolfhugel finally made experiments on pathogenic and non-pathogenic micro-organisms, and found that bacilli, such as the bacillus anthracis, were readily destroyed if free from spores by exposure to sulphur dioxide disinfection; but if the micro-organisms contained spores, prolonged exposure and concentration of the gas had little effect. By steaming a room first, keeping it at the same time at a high temperature, and then afterwards disinfecting, some of the spore-holding material was destroyed, but not all; likewise infected articles wrapped in tow were not disinfected. Small doses of SO_2, acting for long periods of time,

likewise led to no satisfactory result. Wolfhugel's verdict is, renounce disinfection by sulphurous acid gas, for only such agencies should be employed which are fatal to every kind of micro-organism.

(273) *Cash's Experiments on Sulphurous Acid.*

Dr. Cash, F.R.S., has also made experiments with a view to determine the disinfectant value of sulphurous acid. (*Supplement to the* 16*th Annual Report Local Government Board.*)

These experiments are not comparable with Wolfhugel's, for they were made either on solutions of the gas or upon substances suspended in water, and known volumes of the gas passed through the water; nevertheless the information acquired is of the highest value, the acid being made to act upon living infectious material, and the result being tested by inoculation into animals. Solutions of the gas were prepared, the strength of which had some definite relation to the atomic weight of SO_2; for example, 64 parts by weight of SO_2 solution in 1000 grms. of water would be a standard or normal, while 100 c.c. of this solution made up to 2000 would be $\frac{n}{20}$; 100 of the normal solution made up to 3000 would be $\frac{n}{30}$, and so with other dilutions.

Cash found in a strictly quantitative experiment that ·00012 grm sulphurous acid destroyed the spore-free anthrax bacillus in $\frac{1}{50}$ min. of anthrax blood in 5 minutes.

That ·0001 grm. sulphurous acid did not destroy $\frac{1}{2}$ min. of anthrax blood in 5 minutes.

That ·00001 grm. sulphurous acid did not destroy 1 min. of anthrax blood in 5 minutes.

Further that ·00002 grm. of sulphurous acid did not destroy $\frac{1}{50}$ min. of anthrax blood in 5 minutes.

With regard to spores, he found that ·0004 grm. (*i.e.* ·4 mgrm.) sulphurous acid, acting for 24 hours on $\frac{1}{50}$ min. of a minim of an anthrax spore cultivation, destroys it; but if only acting for an hour, the spores are still active.

Experiments were made as to the effect of sulphurous acid solution on the disinfection of tuberculous matter.

A grumous fluid obtained by pounding the tuberculous lungs of a guinea-pig which had died from tuberculosis, in a glass mortar, was diluted with distilled water to 10 c.c. This was found to be disinfected thoroughly when acted upon in an incubator at 37°, in the proportion ·0041 SO_2 to 1 c.c.; but equal parts of $\frac{n}{100}$ acid solution and a strong infusion could act for 28 hours without destroying the virus.

Other experiments were made with tubercular materials placed in a nitrogen bulb with water, and the gas passed through, the result being tested by direct inoculation. A piece of a tubercular lung treated in this way with ·013 SO_2, and removed at the end of 1 minute, produced tuberculosis in a guinea-pig; but ·18 grm. SO_2 and above, acting for 20 minutes, disinfected perfectly.

The writer has also made experiments on the effect of SO_2 on anthrax bacilli, both with and without spores, and obtained very similar results to those already quoted.

We may presume that the infection of most maladies contains resistant spores, and until we have evidence to the contrary, it is safest to discard sulphurous acid, whether as gas or in solution. It is sufficiently proved that only the best results can be obtained when this agent acts under very strict experimental conditions—conditions which may be met with in the scientific laboratory, but not in the practical application of disinfecting agencies in ordinary life, and on a more or less technical scale.

(274) *The Practice of Disinfection. The Disinfection of the Sick-room.*

As an example may be a room in which a person has been suffering from small-pox. The first thing that the disinfector should do is to paste up window and chimney and other crevices with brown paper. Bleaching powder is then distributed in three or four lots about the room. It is best to put some at the highest practical level, others on the ground, all in suitable basins or receptacles. The amount may be in the proportion of 1 lb. to 1000 cubic space. The operator having first seen that the door is open so that his retreat will not be cut off,

and that no living creature remains in the room,[1] rapidly evolves the chlorine by tipping one after the other the requisite quantity of strong hydrochloric or diluted sulphuric acid on to the chloride of lime, and makes his escape (if he should care to breathe through a cloth well charged with moist lime, he may do matters less hurriedly). On closing the door, the next thing is to paste the keyhole and the space around the door, so as to make the chamber as airtight as possible. The room should now be left for 12 hours, then opened, and well ventilated. The room must be now considered *superficially* disinfected, and there will only be trifling danger in handling any article of apparel, or in removing matters for "stoving" through the streets. The next operation is to remove all things that can be washed to the wash-tub, and the bed, cushions, pillows, carpets, and the like to a hot air or steam chamber. This done, the walls may be stripped of their paper, or otherwise cleaned, the floor thoroughly scrubbed, and the articles of furniture well cleansed and polished. There are, however, cases in which the bedroom contains such valuable furniture, or pictures, or other articles of vertu, that chlorine fumigation would entail a considerable money loss. In this case some risk may be run, and sulphur fumigation be resorted to, after which the floor may be sprayed with a 1 per cent. solution of corrosive sublimate, all matters which can be disinfected by heat or steam removed, and the room and its furniture very thoroughly cleansed.

(275) *Disinfection of House Drains and Closets.*

House drains should not require disinfection save when there is sickness in the house. A saturated watery solution of crude carbolic acid, or a 1 per cent. corrosive sublimate solution constantly kept in every closet, and in the bed pans used by the patient, will answer the purpose well. The disinfectant should, of course, be kept in bottles or jars labelled poison, and where there are children the stock should always be under lock and key, and the closets charged by a responsible person.

Other details on practical disinfection will be given when treating of infectious maladies.

[1] I have known cats to have been under articles of furniture and to have been killed by chlorine fumigation.

SECTION VIII.

ZYMOTIC (Micro-Parasitic) *DISEASES.*

CHAPTER XXV.

THE MODERN THEORY OF MICRO-PARASITES.

(276) *Micro-Strife.*

MODERN research has amply shown that the greatest proportion of the maladies, which are more or less preventable, belong to the domain of parasitism. Life preying upon life. The micro-tragedy which may be watched in a highly-magnified drop of pond-water, a voracious monad swallowing up a weaker, is repeated within the body of the mammal. It is scarcely necessary to call to mind, that all the higher animal bodies are but communities of monads or living points, some floating free, others stationary, these last attached to their neighbours by protoplastic bonds of great tenuity (just as adjoining households may have telephonic connection), but with their individuality and automatism unimpaired. A colony of inimical microbes obtaining access to this republic is similar to a hostile armed band entering a city—strife at once commences, the strangers attack and are attacked. If the invaders are all killed, no disturbance of health is produced; in any other event, the strangers increase and multiply at the expense of the normal inhabitants, the latter being rather destroyed by some special toxic substance excreted by the enemy than in any other way.

The analogy of invasion and defence is rendered closer by a knowledge of the fact that the mammalian body has its fighting cells, a soldier-like community, one of whose special offices is to fight; these have been called "*macrophages.*" Under appropriate conditions the fight between macrophage and microbe has been actually witnessed, the former swallowing, as it were, the latter and digesting it. The details of the process have also been followed by

removal of the affected tissues, appropriate staining and observation of the combatants in the several stages—the free microbe and macrophage, the microbe within the substance of the macrophage, but still preserving its outline intact, the microbe becoming cloudy, and final disappearance by complete absorption or digestion. The macrophages themselves are nothing more than leucocytes, cells endowed with automatism and powers of movement, capable of amœba-like pushing out and retracting of portions of their protean bodies.

Each micro-organism seems to have a particular rate of multiplication and those that are pathogenic excrete some toxic substance. We may presume that when a sufficient quantity of the toxic substance is excreted, then and then only the phenomena of general systemic disturbance are experienced. So far as experimental research has gone, there is no true but only an apparent incubation; there is no mysterious localisation for days or weeks of the enemy in lymphatic gland or other tissue. The battle at once commences, and when the victory inclines to the invader then there is sufficient disturbance of function to produce fever, or other symptoms. In some cases there is a general infection, everywhere the microbe can be found, slices of liver, of kidney, of lung, reveal countless myriads of the foreign host, in others, as, for instance, in diphtheria, a portion only of the body is affected, but the poison thus locally developed is carried to every part of the circulation in the same way as when an alkaloid in solution is injected subcutaneously.

(277) *Acquired Immunity.*

By the same theory the curious fact that an animal body having once recovered from one of these micro-parasitic diseases obtains a shorter or longer immunity is capable of a plausible explanation. The macrophages have a rapid cycle of existence, a few hours may represent several generations, so that acquired properties are rapidly transmitted; those poisoned by the excretion of pathogenic microbes perish, those that more or less effectually resist, continue to live and propagate, until by a repetition again and again of this process, the body may be full of resistant living particles, and the foreign tribe is annihilated or expelled. If now a second inimical colony of the same kind obtains access to the body, it

meets with the fighting descendants of the old heroes, and the attack is immediately repulsed, and this is the nature of protection conferred from a recovery from a first attack. Since it would seem that the weapon of the microbe is its venom, it is not surprising that the macrophages may be educated in their resistance by being dosed with the excretory products of pathogenic organisms; the method of education being first doses feeble in either quantity or strength, to be followed by gradually successive doses of increasing virulence, until no health disturbance is produced by an otherwise mortal dose. The efficacy of ordinary vaccination against small-pox may be explained on the theory that vaccine contains a number of degenerate colonies of the same genus as the small-pox microbe, these are conquered with comparative ease ; nevertheless the result is that a race of macrophages are left which, from their education, successfully cope with the virulence of true variola. The remarkable recent investigations of Ferd. Hueppe and Dr. Cartwright Wood, tend to show that even saprophytic bacteria may be used to confer a certain kind of immunity, if they be nearly allied in form, to the pathogenic bacteria, the possible theory being, that the ancestral form of the saprophytic bacteria was pathogenic, but that it has lost nearly all pathogenic properties, save that of splitting up albumen. (See *Public Health*, Vol. II., 269.)

(278) *Classification of Micro-Parasitic Diseases.*

At the present time it is impossible to classify micro-parasitic diseases on a scientific basis. All that can be done is to provisionally arrange these diseases into groups for the purpose of convenience, and for this purpose the author proposes the following :—1. Eruptive fevers. 2. Micro-parasitic diseases affecting the nervous system. 3. Micro-parasitic diseases mainly attacking the respiratory passages. 4. Septicæmic maladies. 5. Tubercular. 6. Malaria. 7. Micro-parasitic maladies primarily affecting the intestine. In considering these different maladies, the chief points which concern the sanitarian, are their method of propagation, the period of quarantine necessary, and the suitable means for isolation and disinfection. Properly speaking the medical officer of health still less the sanitary inspector, has little to do with diagnosis, none with treatment, these things being the business of the medical attendant.

CHAPTER XXVI.

ERUPTIVE FEVERS,

SMALL-POX, MEASLES, SCARLET FEVER, AND TYPHUS.

1. *Eruptive Fevers.*—To this class belong small-pox, chicken-pox scarlet fever, measles, and true typhus.

SMALL-POX.

(279) *Incubation and Eruption.*

The incubation period averages fourteen days, or, to speak more accurately, twelve days intervene, from the first infection to the symptoms preceding the eruption, on the second day of which spots appears, fourteen days being the general period from infection to actual eruption; if, however, small-pox virus be actually inoculated then the incubation period is shorter, about nine days being considered the average.

The general course of an uncomplicated case of ordinary small-pox, is that the patient feels ill, has high fever, the temperature being 104° or above, there is intense pain in the back, a pain not situated in the muscles, and not particularly aggravated by movement, and usually located in the central part of the sacrum. As with all fevers, the high temperature itself disturbs the nervous centres, children have convulsions, adults are drowsy, dull, or may be delirious. Vomiting is a frequent symptom. The eruption appears in three successive crops, first the head and face, then the body, and lastly the legs. The first appearance of the eruption is that of papules, that is, small red spots about the size of a pin's head, although not at first projecting above the surface. On feeling

the spots there is a sensation of a solid body, and as the eruption farther develops each spot becomes a solid nodule ; on either the second or third day of the eruption the spots become vesicular, and of a peculiar shape, for they are flattened at the top, and bound down or umbilicated at the centre ; this vesicular stage lasts about four days, it then becomes pustular but the process is gradual, even on the fifth or sixth day, the central part may be vesicular and on puncture yield clear lymph, while the outer part is purulent and on puncture yields matter. When the vesicle becomes wholly purulent the " bride," which bound down the centre of the vesicles, ruptures, and the vesicle, now becomes acuminated, from this stage to the falling off of the scabs, there is most swelling of the face, when the eyelids are closed, and the disease is in its most repulsive stage. About the eighth day of the eruption a dark spot is seen at the centre of each pustule, here the cuticle ruptures and weeps out purulent fluid, which on drying forms a scab. Now is developed the peculiar sickly smell always to be smelt in cases of bad small-pox. From the eleventh to the fourteenth days the crust becomes detached, and the period of convalescence commences. The general period of actual illness being from fourteen to sixteen days, and eighteen after the falling off of the crusts, it will be usually safe to allow the sufferer to return to his avocations within thirty-two days, precautions to be detailed having first been taken. From the returns of the Asylums Hospital Board, London, it appears that the mean duration of the disease from first eruption to discharge from hospital, in cases returned as " vaccinated," is twenty-five days, the maximum being fifty-five days, the minimum eighteen days, a sufficient number of cases of non-vaccinated cases have not been received to obtain a true average, but it would probably be more than thirty days (the maximum being the same).

The varieties of small-pox are not of the greatest importance to the health officer ; thus, when the eruption is composed of vesicles perfectly distinct one from the other it is called " distinct," when the pustules are so thick that they run one into the other it is called " confluent " small-pox ; when the vesicle dries up and does not develop into a purulent centre it is the mild form of small-pox known as " horn." The method of prevention is however the same in all, and all must be treated as equal in public danger.

(280) *Mortality of Small-pox.*

This varies with regard to the vaccinated or unvaccinated state of the individual attacked, with the virulence of the disease itself, and with the general hygienic condition of the patient's surroundings. The latest experience of small-pox in England of any magnitude is the Sheffield outbreak, which was investigated with so much care by Dr. Barry. Of 4,703 cases of small-pox in Sheffield, of all ages of both sexes, and some being vaccinated, others not, 474 died, equal to a mortality of 10 per cent of those actually attacked. Separating these into two general age groups, 581 children under ten years of age attacked, 106 died, giving a mortality of 18·2 per cent.; of 4,096 persons over ten, 368 died, equal to a mortality of 8·9 per cent.

On separating the cases into two groups, vaccinated and unvaccinated, the following were the very remarkable differences recorded:—

VACCINATED.	UNVACCINATED.
Out of 4,151 cases of all ages 200 died, equal to a case mortality of 4·8 per cent.	Out of 552 cases of all ages 274 died, equal to a case mortality of 49·6 per cent.
Out of 353 cases of children below 10 years of age 6 died, equal to a mortality of 1·7 per cent.	Out of 228 cases of children below 10 years of age 100 died, equal to a case mortality of 43·8 per cent.
Out of 3,774 cases of persons 10 years of age and upwards 194 died, equal to a mortality of 5·1 per cent.	Out of 322 cases of persons 10 years of age and upwards 174 died, equal to a mortality of 54 per cent.

So that it may be laid down that the mortality of all ages and both sexes in a vaccinated community will be under 5 per cent.; in an unvaccinated community it will be over 49 per cent. of those attacked; and if the ratio of the two classes of cases, vaccinated or unvaccinated, be known, the mortality will be in accordance with what may be calculated from the above figures.

(281) *Seasonal Prevalence of Small-Pox.*

Small-pox has a very definite relation to season; the cases are above the average from Christmas till the end of June, the maximum being about the last week in May, the minimum the

last week in September. The following curve is one based upon mortality returns, from Buchan and Mitchell's paper [1]:—

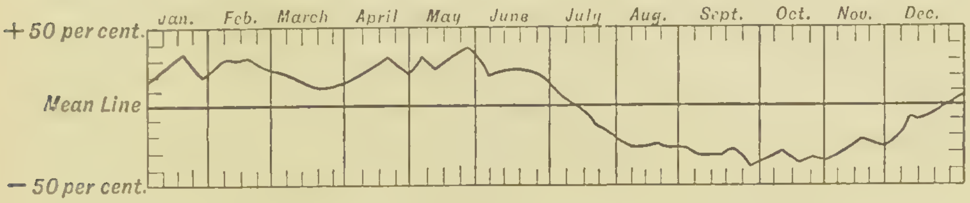


FIG. 48.

The curve represents the average mortality of thirty years, from 1845 to 1874 inclusive, in London. The straight black line represents the mean weekly average death-rate on an average of the fifty-two weeks; with this the average death-rate of each week is compared, and the difference above or below is calculated in percentages of the mean weekly death-rate for the whole year. Thus the mean weekly death-rate for the year is 19·2; the average of the death-rate for small-pox in the first week was 22, which is 2·8 above the average, or 15 per cent; the average for the first week of October is 13, being 6·2 below the average of fifty-two weeks, or 32 per cent.

Death from small-pox usually takes place from the seventh to to the twelfth day. Hence, although the curve is that of mortality only, it is a fair indication of the number of cases, and a medical officer of health, by watching carefully the progress of small-pox in his district, can with confidence early forecast whether it is likely to become epidemic or not. Thus, if there should be cases in December and January, and these increase in the succeeding months, the probability of an epidemic is strong, whereas small-pox absent during the early months of the year would indicate that there would be no epidemic that particular year.

(282) *The Infection of Small-Pox.*

The usual spread of small-pox is from person to person, but from inquiries which have taken place as to the influence of small-pox hospitals upon a surrounding population, and the experience of the Sheffield epidemic, it is certain that the infection can strike at a

[1] "The Influence of Weather on Mortality." *Journ. of the Scottish Meteorological Society*, 1874.

distance. Whether the contagious particles are conveyed by the air itself or by the medium of the common household fly or other insects, the important fact remains that the infection may travel far. The influence of the Sheffield Hospital could be distinctly traced for a circle of 4,000 feet; for instance, the following percentages of households attacked at successive distances from the hospital are given in the original report[1]:—

0—1,000 feet.	1—2,000 feet.	2—3,000 feet.	3—4,000 feet.	Elsewhere.
1·75	·50	·14	·05	·02

This possibility of small-pox spreading by aerial infection increases greatly both the hospital difficulty and that of individual isolation.

(283) *The Duty of the Sanitary Authority and of its Medical Officer in Small-Pox Outbreaks.*

It is specially in the first cases of small-pox breaking out in a town or district that energy and promptitude of action is necessary. The power of mischief that a single case will effect is well seen in the epidemic at the St. Joseph's Industrial School, Manchester,[2] in 1888, in which an imported undiagnosed case infected at one time forty-six inmates and subsequently twenty-three others.[3] It is also well shown in the following case taken from Dr. Birdwood's Report to the Asylums Board, 1888:—

4, Sailor from Port Said, 7th Feb.

5, } Conjectured cases, representing a double period of incubation.
6, }

7, *A Man who died at home 22nd March—ill since 16th March.*

8, Brother, 2nd April.	9, Friend, 3rd April.	10, Betrothed, 4th April.	11, Sister, 3rd April.	12, Father, ill 3rd April.	13, Lodger, about 3rd Ap.	14, Brother, ill 3rd April.

A primary duty is the removal of the patient to an infectious hospital, presuming the sanitary authority to possess one, and that one a sufficient distance from centres of population. Every one

[1] "Report of an Epidemic of Small-pox at Sheffield, 1887-8." By Dr. Barry. Local Government Board. London, 1889.

[2] *Public Health*, vol. i., 174.

[3] See also the elaborate report of Mr. Power. "Statistics of small-pox incidence upon the registration districts of London relative to the operations of small-pox hospitals in the Metropolis, in a succession of chapters." By Mr. W. H. Power. *Sixteenth Annual Report of the Local Government Board* (*Supplement*).

in or around the house or coming to the house should be vaccinated. No person, whatever his position is in life, and however elaborate his nursing arrangements or so-called isolation may be, can be isolated satisfactorily in a private town house; hence, whatever the social position of the sufferer, if the law does not compel, he should at least be persuaded to allow himself to be put apart in a place remote from other habitations.

In many places of course there can be no removal, and in these the medical officer of health will have to exercise his personal authority, all his resources, and ingenuity. It may be possible to empty the house (after vaccination) of all the inhabitants save those nursing the sick: this is the next best thing to removing the patient himself. If there should be choice of a room, one at the top of the house will be preferable, and all unnecessary furniture should be removed, as well as all those carpets, rugs, clothes, curtains, and things not essential to comfort. All excreta should be received in a 1 per cent. solution of corrosive sublimate; the discharges from nose, mouth, or from the eruption generally, should be received on soft old rags and immediately burned. The patient should have a complete set of eating utensils, cups, saucers, &c., devoted to his exclusive use; there should properly be two nurses, one to relieve the other; special dresses or aprons should be supplied to all necessary visitors, who would cover their usual dress during the visit by wearing these garments. Before leaving, washing the hands and face should be insisted upon. The nurses should of course not wear the same dress out as in nursing the sick. In short, the strict management of an infectious hospital should be insisted upon. If the patient should die, the body should be covered with carbolised lime and early coffined. Cases of small-pox attended with delirium may be difficult to manage; the author remembers in his own experience such a case escaping from a house in Lisson Grove and walking down Bond Street, very likely infecting in his passage several people. In such cases personal temporary restraint is absolutely necessary. On convalescence being established a hot bath should be taken daily, and it may be well to oil the skin thoroughly, to wash the oil off, and finally to take a bath of corrosive sublimate solution, 1 per 1,000; there is no danger in such a bath, the solution being too weak to be absorbed in sufficient quantity to poison. After

taking the baths for two or three days, and clean, well disinfected or new clothing being put on, and every scab having fallen, it is probable that the patient is no longer infectious, and he may mix with other people. In those cases however in which the eruption only consists of some twenty or thirty spots, most of which do not go on to suppuration, it is not likely that the amount of infection can be so great as in the severe cases, and it may be safe to consider the case terminated at a shorter period than the month from the appearance of the eruption. There is indeed every probability that three weeks from the first eruption in mild cases may be, with the precautions indicated, a sufficient period of isolation.

(284) *Vaccination and Small-Pox.*

The experimental and statistical evidence as to the efficiency of vaccination in modifying, and in most instances entirely preventing small-pox, is of such a conclusive nature that it is difficult to see why it has been rejected by a section of the community. It is impracticable within the limits of this work to enter into the history of the subject, the last enquiry at Sheffield will therefore alone be summarized, the more especially as the results finally dispose of the assertion that the evident diminution of small-pox mortality is owing to general sanitary improvement rather than to vaccination.

Special instructions were given to Dr. Barry[1] to observe and note carefully every influence that could bear upon the incidence of the epidemic in Sheffield, but no influence was found that had not been dominated by the single influence of vaccination. This influence may be studied first in two great age-groups, and secondly as affecting the population of all ages and both sexes.

First, Children under 10 *years of age.*—Per thousand of the number of children in each class: the attack-rate of the vaccinated was 5; the attack-rate of the unvaccinated was 101; the death-rate of the vaccinated was ·09; the death-rate of the unvaccinated was 44; or stated in other terms: for 100,000 vaccinated children the rate of small-pox mortality actually observed in Sheffield gives 9 deaths; for 100,000 unvaccinated children, the rate of small-pox

[1] "Report on an Epidemic of Small-pox at Sheffield, 1887-8." Local Government Board, 1889. In the above Dr. Buchanan's summary is used.

mortality actually observed gives 4,400 deaths. The above relates to the general children population of the borough. Children living in houses actually invaded were of course exposed to an intenser and more continuous infection, but similar results were obtained thus: Per thousand of the number of children of each class living in invaded houses; the attack-rate of the vaccinated was 78; the attack-rate of the unvaccinated was 869; the death-rate of the vaccinated was 1; the death-rate of the unvaccinated was 381.

Secondly, Persons over 10 *years of age.*—(*a*) Under ordinary conditions, per thousand of the number of persons over 10 in each class: the attack-rate in persons twice vaccinated was 3; the attack rate in persons once vaccinated was 19; the attack-rate in persons not vaccinated was 94; the death-rate among persons twice vaccinated was ·08; the death-rate among persons once vaccinated was 1; the death-rate among persons not vaccinated was 51. (*b*) Persons in invaded houses: the attack-rate of the vaccinated was 281; the attack-rate of the unvaccinated was 686; the death-rate of the vaccinated was 14; the death-rate of the unvaccinated was 371.

Influence of Vaccination upon the Attack and Death-rate of people of all ages living in Sheffield.—(*a*) Living under ordinary conditions: the attack-rate of the vaccinated was 15·5 per thousand; the attack-rate of the unvaccinated was 97·0 per thousand; the death-rate in the vaccinated was ·7 per thousand; the death-rate in the unvaccinated was 48·0 per thousand. (*b*) Living in invaded houses: the attack-rate of the vaccinated was 230 per thousand; the attack-rate in the unvaccinated was 750 per thousand; the death-rate of the vaccinated was 11 per thousand; the death-rate of the unvaccinated was 372 per thousand.

What was true of the fatality was found also true as to the virulence or otherwise of the attack. "From the experience of 1,741 patients treated in hospitals, Dr. Barry reported 17·2 per cent. of severe and confluent cases of small-pox in patients of all ages who had been vaccinated, and 81·5 per cent. of the same forms of small-pox, out of every 100 attacks in people of all ages who had not been vaccinated; for children under 10 the corresponding figures were 9 and 78.

"In the hospitals also the familiar immunity of re-vaccinated persons in attendance on the sick was observed. There were 161

persons employed in the wards and offices of five hospitals. Of the 161, 18 had had small-pox before their engagement, none of these fell ill; 62 persons had been vaccinated in infancy only, of these 6 were attacked, 1 died; the remaining 81 persons had been successfully re-vaccinated, not one of these contracted small-pox."

In the early days of vaccination it was stated to confer full immunity, we now know that this is not correct. Given that several years have elapsed since the vaccination, and that the person is exposed to a large dose of the poison, the disease may be contracted, and the same remark holds good with regard to first attacks of small-pox; the author has himself seen a person pitted from a former attack contract a second, and die. There are evidently some so constituted that protection is evanescent, but the majority are absolutely safe after a successful vaccination, from all ordinary infection, for an unknown and somewhat uncertain number of years. It is probable that re-vaccination every seven years of the population would extinguish small-pox altogether; in any case re-vaccination is to be advised by the medical officer of health, if he should[1] have grounds for forecasting an epidemic, and certainly when an epidemic actually exists. It seems indeed monstrous that with this powerful agency at command, there should be any necessity for spending sums of money on small-pox hospitals, when a complete and thorough compulsory re-vaccination of the community would at once stamp it out. Re-vaccination must be considered in the light of a test—if the vaccination should "take," it is a sign that the infection of small-pox would also "take."

MEASLES.

Measles is a febrile exanthem, highly infectious, more especially prevalent in the early years of life, and but occasionally affecting adults; one attack gives immunity, as a rule, against a second.

(285) *Statistics.*

In this country measles is fatal to from six to fourteen thousand

[1] Re-vaccination would be more sought by numbers of people were it not for the dread of "bad arms," and it cannot be denied that a largish proportion of re-vaccinations are followed by far more redness and unpleasant local sequelæ than primary vaccinations. The reason of this might well be a subject for careful inquiry in the laboratory of the bacteriologist.

children yearly; the mortality per million of the population of all ages being for successive quinquennial periods as follows:—

5 years 1861—65.	5 years 1866—70.	5 years 1871—75.	5 years 1876—80.	5 years 1881—85.
456·6	428·4	373·2	384·8	410·2

It is specially a disease of children; 90 per cent. of the deaths being of children under five years of age: for example, of 12,013 deaths registered from this cause in 1886, the following was the age distribution:—

Under 5	10,878	90·5 per cent.
5	958	7·9 ,, ,,
10	89	·7 ,, ,,
15	28	·2 ,, ,,
20	22	·2 ,, ,,
25	25	·2 ,, ,,
35	12	·1 ,, ,,
45	1	
	12,013	

Of the 12,013 deaths 6,090 were males, 5,923 females. Of the different ages that make up the children under five years of age, the greatest number occur above the first and below the second year of life. The disease being practically confined to children, it would be a more accurate way of considering the mortality to state per population under five years of age, this for the five years ending 1885 is no less than than 2·844 per thousand, or 2,844 per million.

(286) *Seasonal Prevalence.*

Buchan and Mitchell's curve[1] based upon the weekly deaths for the thirty years ending with 1874, shows a double maximum and minimum during the year, the larger maximum occurring in November, December, and January, and the smaller in May and June; the larger minimum in August, September, and October, and the smaller in February and March. The most rapid fluctuation takes place in the fall from Christmas to the middle of February, the weekly deaths falling from 42 to 21. The curve is a very steady one, the maxima and minima being well marked in each of the thirty years.

[1] *Op. cit.*

(287) *Symptoms.*

There is a distinct incubation period, which exhibits but few variations, the initial fever commencing on the 12th, and the eruption appearing on the 14th day after infection. In popular language, measles commences as a violent cold, the eyes are congested and red, the mucous membranes of the nose inflamed, and there is some cough. Not unfrequently the throat is a little sore. In cases of moderate severity, there is considerable fever, temperatures of 104° and 105° being common, while in severe cases the temperature on the 5th day of illness may reach as high as 109°. The eruption fully out, the temperature falls rapidly one or two degrees above the normal standard. The eruption comes out in three crops; it makes its appearance on the third, fourth, and occasionally on the fifth day of the fever; the first crop attacks the face, twenty-four hours after the facial exanthem, the trunk is invaded, and the eruption lastly attacks the extremities. As it appears in one part of the body so it fades in the other. On the 6th or 7th day, it has vanished entirely, and there is a bran like and not very conspicuous desquamation. The eruption consists of small circular pinkish red or raspberry coloured spots; on pressing, there is no feeling of induration as in small-pox eruptions; it disappears on pressure. On looking at the arrangement of the eruption it is very commonly distributed in circinate curves. In very severe cases there may be effusions of blood beneath the skin, as in typhus; measles again is occasionally papular, and on the neck, arms, and breasts, in very young children, vesicles have been known to form. The organs of the chest are in the majority of cases more or less affected, and death when it occurs is for the most part due to pneumonia.

In the mildest cases the eruption does not occur or is so evanescent as to pass unnoticed. Here there are no elements for diagnosis, the symptoms are those of a catarrh. Possibly the "colds" so often seen among adults in times of measles epidemics, are attacks of measles without eruption. To complete the history of measles it must be mentioned that in a few instances there is a well marked eruption but no inflammation of the mucous surfaces.

(288) *Etiology.*

It may be stated with some confidence that measles is one of the micro-parasitic class dependent on some specific microbe. In the blood, in the capillary vessels of the skin, as well as in the catarrhal exudations, cocci and diplococci have been observed,[1] but the bacteriology of measles has not been yet systematically investigated, and it is rather from analogy than from experiment that it may be presumed to be dependent on the specific microbe. The *materies morbi* is in the expectoration, and the cutaneous *débris.* Whether the other excreta are infectious is not known.

(289) *Measures to be taken in Outbreaks of Measles.*

The fact that measles begins as an ordinary cold, and that it is in this stage highly infectious, puts an extraordinary difficulty in the way of the hygienist. Of all diseases measles is most difficult to arrest the spread of in a household. Neither in typhus nor in small-pox, is the disease so intensely infectious in the early days, but in measles we are face to face with a fever which by the time the diagnosis has been formed has already sown its seed in all those who are susceptible of its influence, and who have been brought within striking distance. The striking distance also is probably considerable, at all events its rapid spread in schools under circumstances in which actual contact has not taken place, suggests that it travels to a greater distance through the air than the infection of typhus. Although measures of isolation will in nine cases out of ten be too late so far as the family or household is concerned, it is right to give such measures a trial, and to isolate the first cases of measles directly the affection is recognised, all excreta, whether from the kidneys, bowels, or from the mouth and nose, should be immediately disinfected or destroyed. The only practical method of dealing with rural epidemics of measles has been found to temporarily close the schools of the area infected; this it must be confessed has answered far better in country districts where the children live in isolated communities than in large towns. Measles has not hitherto been treated in infectious

[1] Keating, *Phil. Med. Times*, 1882. Cornil and Babes, *Les Bactéries*, 1885.

hospitals ; to receive measles in hospitals would be a good thing in the interest of most of the patients themselves, but for the reason already given, that is the early development of infection, it is questionable whether the great expense to the community of treating the thousands of cases of measles would be compensated by corresponding advantages. Measles is one of those diseases which requires patient research to elucidate more clearly its nature. If success is attained in this direction, it may be then hoped that some satisfactory scheme of prevention may be formulated.

Scarlet Fever (syn. Scarlatina).

(290) *General Course of Scarlet Fever.—Incubation.*

Typical scarlet fever of ordinary severity is characterized by the following symptoms : On or about the fourth day [1] after receiving

[1] The following remarks as to the incubation period of scarlet fever, by Dr. Clement Dukes, are valuable :—"I think there is no incubation period so variously stated by different authors as that of scarlatina ; I have heard it given from a few hours to twenty-eight days. Yet there is nothing more certain in my opinion than the fact that it never extends beyond a week, and rarely lasts so long. During the time that scarlet fever is prevalent it should be remembered that there is a class of sore throats—to all appearance often only simple acute tonsillitis, while at others having a membranous or sloughy appearance, and with a complete absence of eruption on the skin—occurring in those who have already had scarlatina ; this kind of sore throat, however, is capable of passing on scarlatina to an individual who has not already been affected by it. Scarlatina is often spread extensively by these means ; for if the patient has suffered previously from scarlatina, these sore throats are looked upon as simple non-infectious sore throats, and are consequently not carefully isolated for three or four days, as they should be. Being unrecognized therefore as centres of infection the incubation period of scarlatina is miscalculated accordingly, entailing in consequence, not only a scientific inaccuracy, but sometimes preventible disease and death. Thus A has scarlatina on June 1st, and is carefully isolated on the same day ; but previous to his being isolated he infects or gives off germs which find a nidus in B's throat who has already had scarlatina, with a sore throat which appears on June 5th. B not being isolated for this goes about infecting his school-fellows for a week. Amongst others C, who has not had scarlatina, is infected by him on the last day of the week, June 12th, and on June 16th C shows symptoms of scarlatina. Here A is regarded as the source of infection of C, and his case accordingly is regarded as one of sixteen days' incubation. Again, B infects many boys, who have hitherto had scarlatina, with sore throat only, on various days, and these again others, until some one becomes infected who has not suffered from scarlatina, and in his case true scarlatina appears, perhaps on the twenty-eighth day from A's isolation. We then hear of a case of twenty-eight days' incubation of scarlatina. There is also another not sufficiently recognised source of error in estimating the period of incubation of scarlatina, *e.g.* . . . Some years ago the following episode happened within my experience :—I had a case of scarlatina, and when a week had passed I assured the master in whose house it had occurred that no more cases would arise from this first case. However, many days after, another occurred, and at the end of a week I repeated with confidence my statement that no other cases could arise from the first

the infection, there is sore throat, and a scarlet eruption over the face and neck, the eruption seen in its earliest stage consists of very minute spots and may easily be mistaken for measles, especially as there is often some catarrh and congestion of the conjunctivæ, but these spots rapidly become confluent and the erythematous blush is diffused over the whole surface of the skin, leaving scarcely any healthy oases. On the first day of the eruption it affects the head, neck, and upper part of the body; it keeps extending, attacking on the second day the rest of the trunk, and on the third day the extremities. This order is not constant, for cases are continually seen in which the legs are first affected. The colour varies in different cases in intensity of hue, it may be a lobster red or as dark as the colour of beetroot, in severe cases it may take a livid hue, and be mixed with petechiæ. Bouchut's test is useful in the diagnosis of the eruption. It depends on the fact that the contractile power of the small vessels of the skin is much increased in scarlet fever, hence any pressure on the skin occupied by the eruption gives rise to a more or less enduring white stripe. The mucous membrane of the tongue and cheeks are affected. The papillæ of the tongue are enlarged, they stand up, salient and erect, little scarlet protuberances above a thick, creamy white fur; this appearance of the tongue has suggested to some a likeness to a strawberry, to others the prominent papillæ of the tongue of the cat, hence the term "strawberry tongue," "cat's tongue."

There is another rare class of cases in which the sore throat is absent or nearly so, the rash abundant, and evident, and yet the person feels fairly well. A remarkable case of this kind was communicated to the author by one of the Metropolitan Officers of Health; the case was that of a gentleman who had a perfectly

or second cases, but that we had not yet been able to trace the origin of the first case. This was repeated again several times until we had I think about five cases, all of them with an incubation period of considerably over a week. . . . How to interpret the facts accurately I could not, though I was convinced of the accuracy of my knowledge of the incubation of scarlet fever. However, by and by the unknown quantity was discovered. The boys went home for the holidays, and one of the parents wrote to say that he regretted his son had been allowed to come home with his hands peeling from scarlatina. This boy had never been ill for an hour, consequently no one knew anything about his having scarlatina; throughout the whole time he had gone about infecting his school-fellows, and the only wonder is that he did not infect hundreds instead of units. . . . I strongly affirm that it is a rare thing for scarlatina to occur after the fifth day from exposure, and never after the eighth day; I know of no reliable case on record to the contrary."—*Health at School.* London, 1887.

typical scarlet fever rash, with no sore throat, and the rash was followed by desquamation; the gentleman declared himself absolutely well, and it was with great incredulity that he received the diagnosis of scarlet fever. The difficulty of secluding the above cases is obvious; it is the slight ambulatory cases of scarlet fever which baffle diagnosis, obscure effectually the sequence from case to case, and act as insidious carriers of the disease from person to person. So far as is practical, the Medical Officer of Health should consider every case of sore throat in times of scarlet fever epidemic as likely to propagate scarlet fever, in short to be slight cases of the disease. This recommendation must not be taken to mean the exercise of compulsory powers of removal, for such powers must never be exercised unless the diagnosis is clear, but the recommendation refers to measures of isolation undertaken voluntarily on the advice of the health officer, and especially to the management of schools and public institutions.

(291) *Seasonal Prevalence of Scarlet Fever.*

The prevalence of scarlet fever is distinctly governed by season. The curve given in Buchan and Mitchell's paper,[1] shows that the death-rate begins to rise in the first week of September, attains its maximum in October, commences to decline in December, and is the lowest in March, April, and May. The curve showing the admissions of scarlet fever patients to the Asylums Board Hospitals (see Plate, *opposite*) gives very similar results: during seventeen years the admissions fell to the minimum four times in February, four times in March, five times in April, twice in June, once in September, and once in December. The maximum number was attained once in January (1888), once in July, three times in September, seven times in October, three times in November, and twice in December.

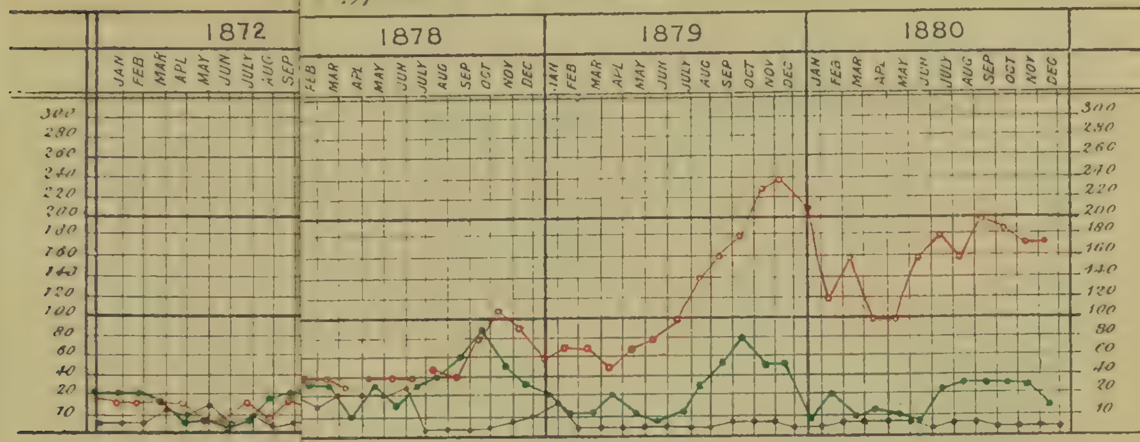
(292) *Mortality of Scarlet Fever.*

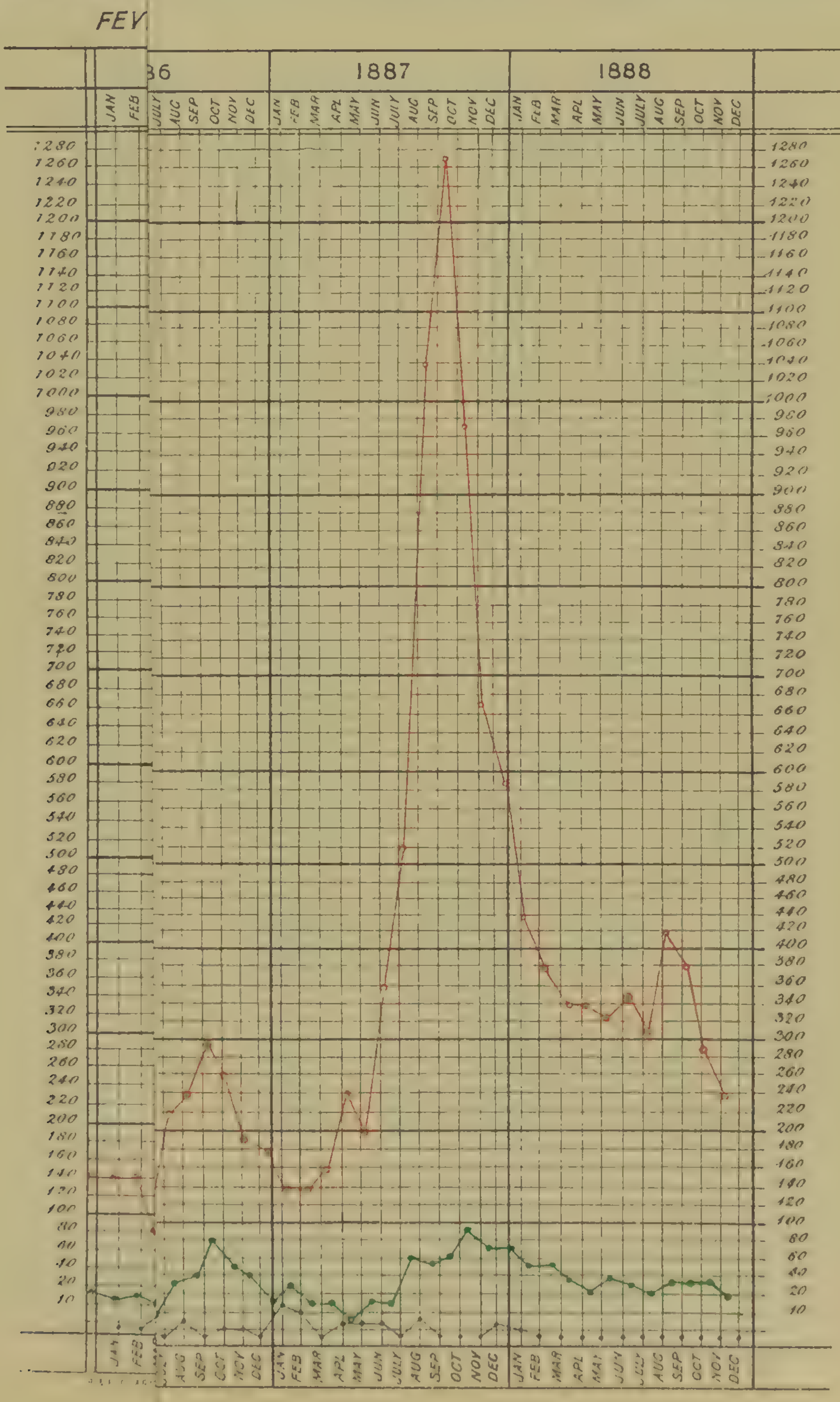
This varies much in different years. During the seventeen years, from 1855–71, the total number of deaths was returned as 321,892, or on an average 18,934 yearly. 67·2 per cent. of these deaths were of children under five years of age.

[1] *Op cit.* see page 369 for methods employed by the authors.

Curves sh[...]ses of Scarlet, Enteric and Typhus fever

, Typhus fever Black line ......





The case and age mortality of scarlet fever can be gathered from the following Table[1]:—

TABLE XL.

SCARLET FEVER.—TABLE SHOWING MORTALITY AT VARIOUS AGES OF 25,788 CASES ADMITTED INTO THE ASYLUMS BOARD HOSPITALS.

AGES.	Males.			Females.			Total.		
	Cases Admitted.	Died.	Mortality per cent.	Cases Admitted.	Died.	Mortality per cent.	Cases Admitted.	Died.	Combined Mortality per cent.
Under 5 ...	3,562	813	22·82	3,525	733	20·79	7,087	1,546	21·81
5 to 10 ...	4,973	433	8·70	5,382	433	8·04	10,355	866	8·36
10 to 15 ...	2,043	93	4·55	2,326	106	4·55	4,369	199	4·55
15 to 20 ...	856	47	5·49	1,131	37	3·27	1,987	84	4·22
20 to 25 ...	398	17	4·27	608	22	3·61	1,006	39	3·87
25 to 30 ...	178	11	6·17	308	13	4·22	486	24	4·93
30 to 35 ...	111	9	8·1	155	12	7·74	266	21	7·85
35 to 40 ...	45	6	13·33	86	5	5·81	131	11	8·39
40 to 45 ...	27	5	18·51	29	1	3·44	56	6	10·71
45 to 50 ...	5	...	...	16	1	6·25	21	1	4·76
50 to 55 ...	10	1	10·00	10	...	...	20	1	5·00
55 to 60 ...	1	1	100·00	1	...	...	2	1	50·00
And upwards	...	...	...	2	1	50·00	2	1	50·00
Totals	12,209	1,436	11·76	13,579	1,364	10·04	25,788	2,800	10·85

N.B.—The above table includes deaths within 48 hours after admission as well as deaths from intercurrent maladies.

Hence, if the deaths from scarlet fever be multiplied by 11, there is a fair probability that the number obtained will approximate to the number of cases occurring in a district.

(293) *Sex and Age.*

The following extract from the *Forty-ninth Annual Report of the Registrar-General* will show the incidence of scarlet fever on sex and age:—

"In the course of the 27 years, 1859–85, nearly half a million deaths from scarlet fever were registered in England and Wales. These deaths form the basis of the following Table, which gives the mean annual mortality per million living at successive age-periods, for each sex.

[1] Metropolitan Asylums Board. *Annual Report of Statistical Committee*, 1888.

TABLE XLI.

MEAN ANNUAL MORTALITY FROM SCARLET FEVER PER MILLION LIVING AT SUCCESSIVE AGE-PERIODS, 1859-85.

Age.	Annual Deaths per Million living.	
	Males.	Females.
0—1	1664	1384
1—2	4170	3874
2—3	4676	4491
3—4	4484	4332
4—5	3642	3556
0—5	3681	3482
5—10	1667	1613
10—15	346	381
15—20	111	113
20—25	59	77
25—35	36	58
35 and upwards	13	15
All Ages	778	717

It will be seen that in each sex the mortality from scarlet fever rises to a maximum in the third year of life, and then falls, at first slowly, but afterwards rapidly, becoming smaller and smaller with each successive age-period, to the end of life.

Further it will be noted that from birth to the end of the tenth year of life, that is to say, throughout that portion of life in which by far the greater part of the deaths from scarlet fever occur, the male mortality is considerably higher than the female mortality, but that after this period the reverse is the case, the excess being in each later age-period on the side of the female sex.

Seeing on what a very large basis these rates have been calculated, both as regards number of deaths and number of years over which they were spread,[1] we may feel assured that the differences here pointed out between successive age-periods and the two sexes are not accidental or transitory, but fixed and permanent; and the question next to be considered is whether

[1] The very variable severity of scarlet fever in different outbreaks makes it necessary, for any trustworthy statistics, to take a long series of years into account.

these differences of mortality are due to the disease being more common, or to its being more likely to terminate fatally in one sex than the other, and at some ages than others. Are the differences, that is to say, differences of prevalence or differences of case-mortality?

The first step in examining this question is to ascertain the case-mortality, that is to say, the proportion of deaths to cases at each age-period and in each sex.

The data available for this calculation are neither so abundant nor so complete as could be wished. The particulars, however, as to age, sex, and results have been obtained in 17,795 cases of scarlet fever admitted during the 12 years 1874–85 into the London Fever Hospital and the Metropolitan Asylums Hospitals at Stockwell and Homerton, and the rates given in Table XLII. are calculated from these 17,795 cases. It was necessary, however, to supplement, to a certain extent, the information obtained from these London hospitals; for the published reports of these hospitals do not distinguish the several years of life in the 0–5 years-period, and, as this is the period of life in which scarlet fever is at its maximum, the separation of these single years from each other is of much importance. This deficiency has been met in the following manner:—The official reports for Christiania in Norway give the full particulars of nearly 5,000 cases of scarlet fever which had occurred there in the years 1870–82. The case-mortality among these attacks for the aggregate 0–5 years age-period differed very slightly from the case-mortality for the corresponding age-period in London, and it was therefore no very great assumption to suppose that there was a corresponding degree of similarity between the case-mortalities in the single years which make up the 0–5 years period. It has been assumed, therefore, that the case-mortality in the 1st, 2nd, 3rd, 4th, and 5th years of life in London differed from the corresponding case-mortalities in Christiania just in the same degree as did the case-mortality in the aggregate age-period, made up of those five years, and the rates given in the table for these first five years are those thus obtained.[1]

[1] The case-mortality in Christiania for the entire 0-5 age-period was, for males 211 per 1,000 cases, while in London it was 241. For females it was 200 in Christiania and 217 in London. The case-mortalities in Christiania for the single years have therefore been raised by 14·22 per cent for males and by 8·5 per cent. for females, to give the mortalities for London.—*Cf. Beretning om Folkemængden og Sundhedstilstanden i Christiania*, 1882, pp. xiii.-xiv.

TABLE XLII.

CASE-MORTALITY.—DEATHS PER 1,000 CASES OF SCARLET FEVER IN HOSPITALS, 1874-85.

AGE.	MALES.	FEMALES.
0—1	395	442
1—2	384	346
2—3	255	226
3—4	184	174
4—5	130	112
0—5	241	217
5—10	106	97
10—15	56	53
15—20	40	34
20—25	39	32
25—35	75	43
35 and upwards	85	65

The figures in this table are very striking, and show beyond dispute how utterly untenable is the statement made, even in some works of high medical authority, that age and sex are without importance as elements in the prognosis of scarlet fever. As regards sex, putting aside the first year of life, when the cases are so few that the accuracy of the calculated case-mortality is doubtful, the danger of an attack of this disease is at every age-period considerably greater if the patient be of the male than if of the female sex. The differences due to sex are, however, as nothing in comparison with those due to age. The chance of a case proving fatal in each sex is highest in the first year of life, and then diminishes rapidly and with unbroken regularity to the end of the twenty-fifth year, after which there is again an increase of risk.

Having now ascertained, firstly, what is the mortality from scarlet fever at each age-period and in either sex, and secondly, what number of cases correspond to each such death, it is of course a simple matter to combine the two tables and calculate the number of cases at each age-period and in each sex for equal numbers living, it being however important to notice that the cases thus obtained will be cases of equal severity to those which

form the basis of Table XLII., that is to say, cases fit for admission into a hospital. The results are given in the following table :—

TABLE XLIII.

ESTIMATED ANNUAL CASES OF SCARLET FEVER, OF EQUAL SEVERITY TO THOSE ADMITTED INTO HOSPITAL, PER MILLION LIVING, AT SUCCESSIVE AGE-PERIODS AND IN EACH SEX.

AGES.	MALES.	FEMALES.
0—1	4,213	3,131
1—2	10,859	11,197
2—3	18,337	19,872
3—4	24,370	24,897
4—5	28,015	31,750
0—5	15,274	16,046
5—10	15,726	16,629
10—15	6,179	7,189
15—20	2,775	3,324
20—25	1,513	2,406
25—35	480	1,349
35 and upwards	153	231

So far our course has been simple, and the results arrived at may be accepted with much confidence, though it may be admitted that it would be more satisfactory were the basis of the table of case-mortality (Table XLII.) enlarged so as to embrace a greater number of cases and a longer series of years. But the next stage in the inquiry becomes much more hypothetical, and the result will consequently be less trustworthy. The question to which an answer has to be sought is, whether the diminution of cases of scarlet fever in successive age-periods, shown in Table XLIII., is merely due to the increased proportion, at each successive age-period, of persons who have already been attacked by scarlet fever and are therefore protected against a future attack, or whether it indicates a diminishing susceptibility to the infection with advance of age in those who are as yet unprotected. It will not be difficult to obtain an answer to this question if the figures in Table XLII. represented the general case-mortality and not merely the mortality of hospital cases; but, though scarlet fever patients are sent into hospital not only when they are severe cases, but often simply in order to separate an infectious child from the

rest of the family, it cannot be doubted that on the whole the average of the hospital cases will be of more than average severity, there being notoriously a large number of scarlet fever cases in which the ailment is so slight that it would not occur to the parents to send the child away from home. Consequently the case-mortality as given in TableXLII. is almost certainly much too high; it is true for hospital cases, but not for all cases. Now there are some large towns in which returns are made of all known cases of scarlet fever, whether occurring in or out of hospitals, and, though these returns are neither of sufficient magnitude nor of sufficient certainty to afford a very secure basis, yet they afford some assistance, and judging by them we shall probably not be very far from the mark if we assume that, for every individual who is protected against future scarlet fever by an attack of equal severity to that of an average hospital case, there is another person protected by an attack of less severity. Let it be assumed then, that this is true, and then the next step can be taken; the proportion of the population that is protected at each successive age-period in each sex can be calculated, and the proportion between the cases and the unprotected population ascertained. The results of this somewhat tedious arithmetical process are given in the following table:—

TABLE XLIV.

ESTIMATED[1] ANNUAL NUMBER OF ATTACKS AND DEATHS BY SCARLET FEVER IN A MILLION UNPROTECTED PERSONS OF EACH SEX AT SUCCESSIVE AGE PERIODS.

AGE.	ATTACKS.		DEATHS.	
	Males.	Females.	Males.	Females.
0—1	6,779	4,887	1,668	1,386
1—2	17,758	18,723	4,220	3,916
2—3	33,065	36,480	4,832	4,647
3—4	47,385	48,874	4,801	4,657
4—5	58,906	68,036	4,095	4,036
5—10	37,524	40,423	2,100	2,060
10—15	17,332	20,817	499	567
15—20	8,365	10,508	171	182
20—25	4,714	7,972	94	130
25—30	1,491	4,585	58	101
30—35	472	787	21	26

[1] Estimated on the assumption stated above.

The figures in this table cannot of course claim to be more than approximate estimates. More precise results will be hereafter obtainable, when the case-mortality can be based upon a larger accumulation of data than was available for the construction of Table XLII., and which shall include the cases outside as well as those within hospitals. Allowing, fully, however, for this element of uncertainty as to the precise figures, we are nevertheless able to draw with much certainty the following conclusions as to scarlet fever :—

1. The mortality from this disease is at its maximum in the third year of life, and after this diminishes with age, at first slowly afterwards rapidly. (Table XLIV.)

2. This diminution is due to three contributory causes : (α) the increased proportion in the population at each successive age-period of persons protected by a previous attack ; (β) the diminution of liability to infection in successive age-periods of those who are as yet unprotected ; (γ) the diminishing risk in successive age-periods of an attack, should it occur, proving fatal.

3. The liability of the unprotected to infection is small in the first year of life, increases to a maximum in the fifth year or soon after,[1] and then becomes rapidly smaller and smaller with advance of years. (Table XLIV. Cols. 1, 2).

4. The chance that an attack will terminate fatally is highest in infancy, and diminishes rapidly with years to the end of the twenty-fifth year; after which an attack is again somewhat more dangerous. (Table XLIV.)

5. The female sex throughout life, the first year possibly excepted, is more liable to scarlet fever than the male sex. (Table XLIV.)

6. But the attacks in males, though fewer, are more likely to terminate fatally. (Table XLIV.)

Now it is sometimes said that the separation from its family of a child who is attacked by scarlet fever is scarcely worth the trouble and expense it involves, seeing that the rest of the children, though they may escape on that special occasion, are almost certain to contract this very common disease at some future

[1] The Table does not suffice to show whether the fifth year be the year of actual maximum. For as the 5–10 year-period is not broken up into separate years the maximum might possibly be in the sixth or even seventh year.

time, and may therefore as well, if not preferably, have it at once. The results, however, to which our statistical inquiry has led us, are completely subversive of such a position. They show—independently of the plain fact that a very large proportion of persons go through life without ever contracting this disease—that the longer an attack is deferred, the less likely it is to occur at all; and not only so, but that, even supposing it to occur eventually, the less likely it is to end fatally."

(294) *Sequelæ and Complications of Scarlet Fever.*

Of late years the relative frequency of different complications of scarlet fever has been studied on a large scale in the hospitals connected with the Asylums Board, and the various reports of the Statistical Committee constitute a veritable mine of information. A curious circumstance about these reports is however the undoubted fact that scarlatina derived from one part of the Metropolitan area does not present the same percentage of complications as another; for instance, in the 1887 epidemic, in the Eastern Hospital, albuminuria complicated the cases in the proportion of 4·9 per cent. of the attacks, while in the Western Hospital, in the same year and the same epidemic, albuminuria prevailed in the proportion of 35·6 per cent.; it may be suggested that the staff of the one hospital more diligently examined the urine than of the other, but there are similar differences with other diseases; take, for example, otorrhea: in 1887 the Eastern Hospital records show, in over 1,000 cases, that otorrhea prevailed in the proportion of 4·3 per cent., in the Western 11·0 per cent. Hence it is impossible to be dogmatic with regard to the relative frequency of particular complications: it may however be useful to give the following percentages observed, compiled from 1,115 cases of scarlet fever admitted into the Western Hospital in 1887:—

	Per cent. of attacks.
Albuminuria	35·6
Adenitis (inflammation of glands of neck)	25·4
Rhinitis	11·3
Otorrhea	11·0
Nephritis	5·6
Abscess (mostly cervical)	3·8
Arthritis	3·0
Stomatitis	1·9
Conjunctivitis	·7

To this may be added a long list of less frequent complications, such as hæmaturia, pyæmia, convulsions, dropsy, peri and endocarditis, laryngitis, cystitis, and others. It must be specially noted that the complications mentioned above rarely occur simply, they are for the most part compound, that is, a person will suffer at once from albuminuria, otorrhea, and abscess, or other combinations.

Dr. Sweeting has observed the remarkable fact that albuminuria has been on the increase in the Western Hospital in successive epidemics, due, as he considers to decreasing cubic space, the wards becoming in successive years more crowded with patients. He gives the following table:—

Table XLV.

Albuminuria, 1882–1887.

Year.	Number of completed cases.	Number of these which presented Albuminuria.	Rate per cent.	Remarks.
1882	64	9	14·0	Heat and nitric acid used as a test for albumen.
1883	248	61	24·5	Picric acid first employed in early part of year.
1884	89	17	19·1	Picric acid exclusively employed.
1885	180	39	21·6	,, ,, ,,
1886	343	101	29·4	,, ,, ,,
1887	1,115	397	35·6	,, ,, ,,

The same increase of albuminuria has been noted by Dr. Thorne, late physician to the London Fever Hospital, who says,[1] "There have been occasions when, owing to repairs or otherwise, it has been found necessary as a temporary measure to exceed the number of patients properly allotted to one or other ward, and when this has been the case the practice has almost invariably been followed by an increase in the number of patients exhibiting albumen in the urine."

It may well form the subject of inquiry whether the curious odour given off by lungs and skin in the worst form of scarlet

[1] *Practitioner*, December, 1887.

fever is not some volatile toxic matter producing albuminuria, if so, it would be a reasonable explanation of the above facts. Whatever the cause of the increase, such observations are additional arguments for the amplest cubic space in infectious hospitals.

(295) *Period during which it is necessary to isolate Scarlet Fever Patients.*

It is to be hoped that accurate observations based upon experimental data will ere long be forthcoming, so as to enable us to know when a patient ceases to be contagious; at present we have to rely solely upon the length of desquamation or discharges. That in the prolonged "peeling" of some cases of scarlet fever the debris contains the scarlatinal infection is more a matter of inference than actual proof, but until the question is settled, it will be safest to take the period of seven weeks from the beginning of the illness as a rule for ordinary cases, *provided the desquamation is finished,* and this is the opinion of Dr. Gayton,[1] the superintendent of the North-Western Hospital, whose observations may be quoted verbatim :—"The variableness of desquamation, or peeling, is by all medical men admitted. Occasionally a long period elapses before the whole of the cuticle has separated—six weeks, two months, and longer; indeed, that on the *soles* of the feet may often be seen peeling long after the desquamation on the rest of the body has ceased, when the patient is perfectly well, and has been walking about, perhaps, for a long time. Again, it may be so slight as to be perceptible about the roots of the nails only, or so considerable as to cover the whole place with dust every time the patient shakes himself, during the whole of which time, however, it would be utterly wrong—nay, criminal—to sanction any inter-communication with the healthy. Enforced isolation, after a time at least, is no doubt very hard, especially in cases where the disease is slight, where there is no sense of illness, and but slight or no appearance of desquamation, but, nevertheless, it is sound doctrine; the precaution may appear needlessly excessive, but the case is one for great caution. As a matter, therefore, of sanitary precaution against the dissemination of infection, it is,

[1] Metropolitan Asylums Board. *Annual Report of Statistical Committee,* 1888.

from my point of view, utterly wrong to permit any scarlet fever patient whatever to mingle with persons susceptible to the disease until the expiration of seven weeks from the beginning of the illnesss, and in those cases where the desquamation is of late appearance, until the process is completed, and for a fortnight afterwards, nor then, unless there is entire absence of discharge from the nose and ears, and the clothes worn on discharge are clean and thoroughly disinfected."

(296) *The Connexion of Scarlatina with Disease in Milch Cows.*

That in some way or other milk conveys the cause of scarlet fever has been many times noticed, but it was not until the inquiry by Mr. Power into an epidemic of scarlet fever (1882) in St. Giles and St. Pancras, that there were sufficient grounds for believing that the cow itself may secrete milk which, independent of human agency, is an infectious fluid, and will give those drinking such milk, who are susceptible of the poison, scarlet fever. To quote Buchanan, in this epidemic "two facts could be affirmed; the one, that a cow recently come into milk at a particular farm had been suffering from some ailment, seemingly from the time of her calving, of which loss of hair in patches was the most conspicuous manifestation; the other, that there existed no discoverable means by which the milk, which had coincided with scarlatina in its distribution, could have received infective quality from the human subject." The facts, although imperfect, were so far suggestive that, at the instance of the Local Government Board, Dr. Klein made some experimental observations as to the concern of animals with human scarlatina, and it was found that, particularly when a cow was in milk, a definite disease was producible in the animal by means of scarlatina infection, the disease was capable of being communicated from one animal to another by inoculation.

In 1885 new light was thrown upon the subject, by what is known as the Marylebone epidemic. The author reported to the Local Government Board a sudden and extensive outbreak of scarlet fever that was evidently connected with a particular milk supply. The retailer obtained his supply from two farms, and the coincidence of the retail milk distribution with scarlatina was limited to one portion of the milk, which portion only was

derived from a certain farm at Hendon. Mr. Power was deputed to investigate the matter, and he found that milk had been distributed by retail in St. John's Wood, in St. Pancras, in Hampstead, and at Hendon, and in these districts only, and from every one of these districts, except from St. John's Wood, the same general story was forthcoming. "Until the end of November or beginning of December, 1885, the district had been for some months exceptionally free from scarlatina; about this date scarlatina had undergone a sudden and notable increase in the district, and then and thenceforward a strikingly large proportion of the recorded cases had occurred among persons who proved, upon inquiry, to be customers of the milk retailer dealing in the particular Hendon milk."[1] A very strict inquiry at the Hendon farm seemed to put beyond a doubt, that the milk had not been contaminated there by human agency.

By a series of facts amply detailed in Mr. Power's report, among which the exemption of the St. John's Wood customers occupied an important link in the chain of evidence, the infected milk was traced to a particular cowshed, and to particular cows. In the end it was demonstrated beyond a reasonable doubt that in December these cows suffered from an eruptive disease of the udder and teats, a condition first introduced there in the previous month by some cows newly arrived from Derbyshire.

Products derived from the affected animals were studied by Dr. Klein, and two of the cows were purchased and conveyed to the Brown Institution.

Dr. Klein[2] made a series of researches with this material, and the results of which up to the present are as follows:—

The cow disease is characterised by closely similar anatomical features to the disease in man. From the diseased tissues and organs of man and cow alike a streptococcus can be separated which has the following characters. The streptococcus grows on gelatin in opaque white colonies, and it does not liquify the gelatin. It is slower of growth than most micrococci. After a long time (several weeks) it has a fairly distinct but slightly irregular and crenate outline here and there, beset

[1] *Fifteenth Annual Report of the Local Government Board* (*Supplement*), 1885-6.
[2] *Seventeenth Annual Report of the Local Government Board* (*Supplement*), 1887-8, p. xiii.

with dark knobs or linear processes (see Fig. 49, which shows the appearance of an artificial culture on gelatin × 3). When grown in milk it coagulates the milk. If the inoculated milk be kept for two days in the incubator at 35° this distinguishes it from the streptococcus of foot and mouth disease, to which it has otherwise remarkable resemblance. Some of the elements may be as diplococci or as short chains. Cultivated in broth it forms long and

FIG. 49.

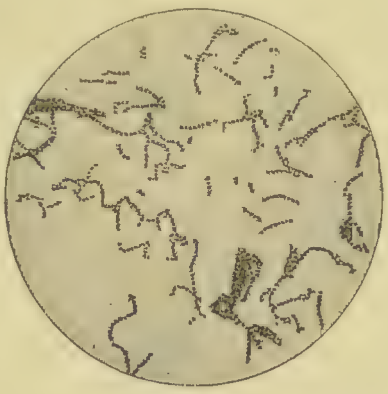


FIG. 50.

exquisite chains (see Fig. 50, which is from a photograph of a subculture in broth). The elements of the chain are a little larger than those of foot and mouth disease.

Subcultures of the micrococci have the property when inoculated into calves of producing in them every manifestation of the Hendon disease, except sores on the teats and udders, and subcultures from human scarlatina inoculated into recently calved cows can produce in those cows, along with other manifestations of the Hendon disease, the characteristic ulcers on the teats—ulcers identical in character with those observed at the Hendon farm.

The post-mortem appearances of the chief organs affected are represented in Plate I. from Dr. Klein's original drawings. A is a section of the spleen of a cow which had been artificially inoculated with a culture of the streptococcus derived directly from human scarlatina. The gland was slightly enlarged, of a dark colour, and in the section numerous petechiæ are observed; B is a cut bronchial gland showing pigment and extravasated blood in

the cortical lymph sinuses and in the medulla; C is a portion of the lung showing numerous petechiæ.

The subcultures produce in rodents a disease pathologically similar to cow and human scarlatina.

Calves fed on subcultures established from human scarlatina obtain the Hendon disease.

Children (as proved by the Marylebone epidemic) fed on milk from cows suffering from the Hendon disease obtain scarlatina. The above, Dr. Buchanan [1] justly remarks, form a mass of evidence that the Hendon disease is a form occurring in the cow of the very disease that we call scarlatina when it occurs in the human subject.

So far the evidence of the Local Government Board's scientific staff; their conclusions are not, however, accepted in their entirety by all bacteriologists. In particular Professor Crookshank maintains that a disease in Wiltshire, apparently identical with the Hendon disease so far as external appearances go, is cow-pox, and infers that the Hendon disease was also cow-pox; to which Dr. Klein replies that there can be no question that the Wiltshire "is not the disease I saw at Hendon, and now known as cow-scarlatina. Inasmuch as both are ulcerative diseases showing ulcers particularly on teats and udders, the two no doubt resemble each other. In so far as the ulcers have the structure of ulcers, the ulcers (if we may ignore considerations of duration) again have resemblances *inter se*. In so far as they are communicable from animal to animal, they are both of them infectious diseases. Also they both have micrococci in the discharges of the ulcers, though the micrococci differ in their characters. But there, it seems to me, the similarity ends."

Drs. Edington and Jamieson have also investigated scarlatina by biological methods. Edington, from his researches, ascribes the true cause of scarlatina to a motile bacillus.

It is unfortunate that hitherto no eminent bacteriologist has either confirmed Klein's researches or any of the other rival theories. The last research of Klein, in which he has succeeded in reproducing the Hendon disease by inoculations of human scarlatinal matter in recently calved cows, is most important, and

1 Report by Dr. Klein on a Disease of Cows. *Fifteenth Annual Report of the Local Government Board* (*Supplement*), 1885–6. "The Morphology and Biology of Streptococcus," by Dr. Klein. *Seventeenth Annual Report of the Local Government Board* (*Supplement*), 1887–8.

could easily be tested. Taking the whole evidence together, it generally tends to prove that Klein's views are correct, but in such a complicated and difficult subject we must not too hastily accept them.

Typhus.

Typhus fever is peculiarly a disease of crowded poor centres of population. Hence it is specially Medical Officers of Health in charge of large towns who are likely to have an opportunity of seeing cases of typhus.

It is characterised by a high temperature, great muscular prostration, a distinctive eruption, is highly infectious, and one attack confers as a rule immunity against a second.

(297) *Statistics.*

The diminution of the number of deaths from typhus in modern times is remarkable. Before 1869 the Registrar-General included under one heading three classes of continued fever, but since that date there have been separate returns; 4,281 deaths from typhus were returned in 1869; with a few unimportant exceptions the deaths declined year by year to 318 in 1885; or, put in another way, the death-rate for typhus has declined from 193 per million in 1869 to 12 per million in 1885. In 1887 there were admitted into the Asylums Hospitals 36 cases; in 1888 only 1, and in 1889, 23 cases.

(298) *Incubation Period.*

There seems to be a real variation in the period of so-called latency. In 31 cases carefully observed by Murchison, in 1 case it was not less than 21 days; in 1 exactly 15 days; in 1 not less than 14 days; in 1 not less than 13 days; in 4 exactly 12 days; in 13 a period of 12 days was within the known limits; in 2 it was not more than 10 days; in 1 not more than 6 days; in 1 exactly 5 days; in 1 between 5 and 2 days; in 2 there was not more than 4 days; in 1 not more than 2 days; and in 2 there was no latent period, or only one of a few hours. From whence it may be gathered that 12 days is the most usual period, and that with regard to the question of quarantine a period of 15 days will take in nearly all the cases.

(299) *Symptoms.*

The advent of typhus is nearly always sudden. It may be preceded by the usual indefinite slight headache and malaise for one or two days, but oftener the date is sharply defined by rigors, frontal headache, lassitude, pain in the back and limbs (especially in the thighs), and a high temperature. The temperature on the second day is mostly above 102°, by the fifth day above 103°, and may reach 105°. A fever in which by the fifth day the temperature is not higher than 102° is probably not even a mild attack of typhus. In severe cases the temperature is very high—104° to 104·9° on the second or third day. Between the fourth and seventh days, but usually on the fourth or fifth, there is an eruption. The eruption, when it first appears, is specially likely to be confused with the eruption of measles. The spots are small, varying in diameter from a few lines to mere specks, and grouped together in patches with an irregular outline. At first of a dirty pink, and slightly elevated above the surface of the skin, they disappear on pressure, but after the first or second day they become of a darker colour, and on pressure only get paler.

The best place to look for the eruption is on the back. The eruption is often scanty, and in dark-skinned races difficult to see. There may also be difficulty in detecting the eruption in the lower orders from the presence of dirt, as well as in kitchens and dark rooms from the absence of a good light. The eruption is present in 97·7 per cent. of the cases, when looked for by skilled and experienced observers. As it does not appear until the fourth day, and it may be later, in the first cases of a typhus epidemic, the patients will probably be not moved to hospital before the fifth or sixth day. The eruption does not appear in successive crops; they all appear as a rule within 24 hours of the commencement of the eruption. About the second week of the disease minute hæmorrhages take place subcutaneously, giving rise to purplish spots or petechiæ. These, of course, do not disappear on pressure. The frequency of petechiæ has given rise to one of the synonyms of typhus fever, viz., "petechial fever," but petechiæ in the milder cases may be absent. On the other hand, they are sometimes to be seen at the commencement of the malady. A very good representation of the eruption on the skin in its different

stages is given in Murchison's classical work on *The Continued Fevers.*

The petechiæ have been confounded with flea-bites and *vice-versâ.* In the author's experience a child, three years old, during an epidemic of typhus, was sent upon the certificate of a physician to the hospital, but the authorities returned the child two days afterwards, stating the spots were those produced by fleas—a curious error, the more so because the petechiæ of typhus are not very similar. A close examination with a lens will reveal the fine puncture in the centre of the spot made by the piercing apparatus of the little vampire.

About the end of the first week delirium sets in. The delirium may be acute, although this is rare. It is, however, important to remember that cases have been known in which the patient has escaped from his attendants and appeared in the street. Fortunately, owing to the rapid manner with which abundance of fresh air dilutes and renders innocuous the typhus poison, this circumstance is not very dangerous to the public, a chance meeting of a delirious patient in the open street being probably more alarming than infective. Nevertheless, the possibility of such an occurrence shows the necessity of isolation in a suitable place, and nursing by trained nurses.

After three or four days of delirium succeed nervous depression and stupor. The muscular prostration is extreme, the patient lies in bed with vacant stupid countenance, the conjunctivæ injected, the eyelids closed, and the pupils contracted, the tongue dark brown and coated with sordes. There may be tremors, subsultus, and picking of the bed-clothes. The pulse is frequent, small, and undulating. The bowels nearly always confined. The urine generally copious and either evacuated involuntarily, or having to be drawn away by a catheter. In this state the patient passes many hours or several days with life trembling in the balance; if the case is to terminate fatally the stupor passes into profound coma, or sudden engorgement of the lungs suffocates the patient, or a combination of syncope and coma supervene. If the case is to terminate in recovery, then on or about the fourteenth day there is a more or less sudden amendment, the patient falls into a quiet sleep from which he wakes another man. Recovery is now rapid. In a week there will be only left great muscular weakness, and often also some cerebral debility, both to be completely recovered from.

(300) *Etiology of Typhus.*

It is only by analogy that typhus is classed with diseases supposed to be of micro-parasitic origin. The truth must be told that concerning its real nature we know extremely little. There are some grounds for believing typhus to be the emasculated plague, in a few cases of typhus there are purulent swellings very similar to the buboes and abscesses of the plague, and it is a circumstance of some significance that Clot Bey, the eminent Egyptian physician, on visiting the London Fever Hospital some years since, saw cases of typhus complicated with swellings in the parotid region, and declared that such cases in Egypt would be called cases of the "Plague." There have only been isolated bacteriological observations on cases of typhus; for instance, Mott[1] has described active motile dumb-bell cocci in the blood, and plugs of cocci in the lymphatics of the heart, but no elaborate sustained inquiry into the nature of typhus has been made by modern methods. Typhus has in all historic times marked out for its peculiar habitat spots where human beings heaped themselves together in poverty and mental misery. Of all predisposing causes the most fertile have been overcrowding, mental and bodily depression. It has followed the wake of armies, it has penetrated with the felon into the jail, it has sailed in the slave ship, and become endemic in the lowest and most densely populated parts of large cities.

"A careful study," says Murchison, "of the history of typhus epidemics demonstrates, in my opinion, the intimate connection between these epidemics and famine or distress. They have appeared during every variety of climate, season, and weather; famine and overcrowding have been the sole conditions common to them all." Murchison even went so far as to believe that under these circumstances typhus might be produced *de novo*, but this doctrine will not be accepted at the present day. Presuming it to be caused by a micro-parasite, it is known that many of these live under ordinary circumstances as saprophytes on vegetable and other organic matter; it is therefore more reasonable to suppose that, instead of a creation of the typhus poison, it ever exists, and under certain circumstances attacks human beings.

Whatever may be the nature of typhus poison there is good

[1] *British Medical Journal*, 1883.

evidence to believe that it is lighter than atmospheric air. Haller found that ozone introduced into a typhus ward was most rapidly consumed in the upper part of the room. It has also been observed that if typhus be treated on the second floor of a hospital, patients, on the third or upper floors are likely to catch it, while on the contrary, if the typhus patients are placed at the top, the infection does not descend. The bodies of typhus patients emit a peculiar odour, and the odour is supposed to be connected with the infection; those patients who have the strongest odour are most apt to communicate the disease. The typhus poison is most probably thrown off by the skin and lungs, and taken in by breathing. The striking distance of typhus is important; the oldest observations are those of Haygarth, on the subject. In 1777 he devoted much attention to this matter, and concluded that the infectious matter of small pox does not exceed half a yard, and that the contagion of typhus is confined to a much narower sphere. We, however, now know that this opinion with regard to small pox is entirely misleading. Lind, Tweedie, and Murchison all, however, agree that the typhus poison only strikes within a very small distance, probably a fever hospital taking typhus patients may be situated in the centre of a large population without public danger; at all events no indictment has been laid against the London Fever Hospital, and at no time has typhus fever prevailed in its neighbourhood in such a manner as to suspect the hospital as the cause. Murchison says, "From all experience it follows that if a typhus patient be placed in a large, well ventilated apartment the attendants incur little risk, and the other residents in the same house none whatever. There are likewise no grounds for the popular belief that typhus may be propagated through the atmosphere from a fever hospital to the houses in its neighbourhood. On the other hand, medical men who auscultate typhus patients, or who inhale their concentrated exhalations from under the bedclothes, run no small danger, and the danger is always increased or diminished in proportion to the supply of fresh air."

The typhus poison adheres to clothes and woollen or organic substances generally, but if these are exposed to the air it becomes innocuous; no instance is on record of a medical man carrying typhus home to his family, although some have been in constant attendance on typhus patients. On the other hand, if clothes infected with typhus have been tied up in bundles or put away in boxes or

drawers, or have been kept under other conditions which have prevented full areation, under these circumstances the infection may be long retained, and in medical literature may be found several instances in which fomites have conveyed the infection after a considerable time has elapsed.

From available evidence it appears that the first few days of illness are not so infectious as when the fever is at its height and during the period of convalesence. Murchison says, "My opinion is that the disease is really most contagious from the end of the first week up to convalescence, when the peculiar odour from the skin is strongest, and that the body ceases to give off the poison as soon as the fever subsides and the appetite and digestion are restored. During the first week of typhus there is little danger, when the patient is removed within this time the disease rarely spreads." If this doctrine be accepted patients should be safe to discharge from hospital a week after the complete cessation of the fever. The evidence as to whether a dead body of a person dying from typhus is contagious or not is far from clear, but it is safest to consider such a corpse contagious, and to take measures accordingly.

(301) *Mortality.*

The mortality calculated from 18,268 cases admitted into the London fever hospital during the years 1848-59 was 18·9 per cent. of the cases, but the mortality from more recent statistics is less; for instance, in 54 cases of typhus in an outbreak in St. Marylebone in 1881 the mortality was 15·6 per cent, and in 1887 the case mortality of typhus treated at the hospitals of the Asylum Board was only 11·6 per cent. Typhus is not alone less prevalent but less mortal than formerly.

The mortality is greatly influenced by age, the mortality being lowest among children from 10-14 years of age, highest in adult life; for example, in cases admitted to the London Fever Hospital between the years 1862-70 the following was the age-distribution mortality:—

Age.	Mortality per cent.
Under 10 years	3·27
From 10—14 years	1·67
,, 15—19 ,,	3·96
,, 20—29 ,,	12·34
,, 30—39 ,,	22·63
,, 40—49 ,,	35·97
Above 50 years	57·03

It used to be stated that the predisposition to infection was less in children, more in adults, and the rule laid down was that the bread-winners of the family are first struck down, then the children, but this does not coincide with the more recent experiences, see p. 404.

Males are a little more liable to die from typhus than females. The cause probably mainly is the greater muscular development. Typhus fever is a fever in which there is disintegration of muscle and poisoning of the system from the products; hence it is an old observation that patients with strong muscular development bear typhus ill, and that the mortality is greater among such. Besides this males on the whole are more intemperate than females, and are more liable to kidney complications; intemperance in itself predisposes.

(302) *Seasonal Prevalence.*

The prevalence of typhus is a little influenced by season. Buchan and Mitchell's[1] curve shows that typhus is above the average from January to the beginning of May, and, with the exception of the hot season of July, in which it is very slightly above, it is slightly below the average from the middle of May to the end of September; it rises decidedly in the first week of October, and decreases in the middle of December to again rise towards the end of the same month. They, however, rightly remark that "it is a curve which calls for clearer definition from future observations, though it has two maxima, the larger in the early months of the year, and the smaller in the height of summer." The mortality curve of Buchan and Mitchell does not altogether agree with the admissions into the London Fever Hospital in the different months of the year; thus the 18,268 cases admitted from 1848-1870 were distributed through the months as follows:—

January	10·8 per cent.	July	6·8 per cent.
February	8·8 ,, ,,	August	6·4 ,, ,,
March	10·4 ,, ,,	September	6·3 ,, ,,
April	8·9 ,, ,,	October	7·8 ,, ,,
May	8·3 ,, ,,	November	9·1 ,, ,,
June	7·1 ,, ,,	December	8·8 ,, ,,

[1] *Journal of the Scottish Meteorological Society*, July 1874-75.

The general fact that it is more prevalent in cold, less prevalent in mild, weather, has been explained by saying that in the cold months of the year the poor shut their windows and therefore the ventilation being less typhus spreads easier, a very feasible explanation, if the December and July portions of Buchan and Mitchell's curve can be explained away; otherwise not so.

(303) *Race.*

It is not known whether typhus irrespective of personal habit and general environment attacks one race rather than the other, the broad fact that in England typhus is more especially disastrous among the Irish is incontestable, but it is among the Irish that there has been most overcrowding and poverty, a sufficient cause of greater prevalence. In the years 1848-67 there were admitted into the London Fever Hospital:

1 in every	135	of the	Irish inhabitants of London.
1 ,,	223	,,	English.
1 ,,	397	,,	Scotch.
1 ,,	404	,,	foreigners resident in London.

showing a considerable incidence on the Irish race.

(304) *Prevalence of Typhus in* 1886.

In 1886 the Medical Department of the Local Government Board[1] made a special inquiry as to the existence of typhus in the country, and Mr. Spear, to whom was entrusted the investigation, made a most instructive report. For one reason or other 67 districts came under suspicion; in most of these where fever was found it proved to be the ordinary enteric fever of the country, but in no less than 17 important centres of population typhus was found existing; for example, at Leeds 56 cases in 33 families were reported between October 26th, 1886, and 28th of January, 1887, nearly all occurring among the Irish, in a locality in which the people were poor and ill-housed. "Unrecognised cases among children had occurred in this infected area before the date assigned to the earliest reported case."

At Middlesborough a localised outbreak of typhus occurred in

[1] *Sixteenth Annual Report of the Local Government Board* (*Supplement*). Report of Medical Officer for 1886.

the latter half of 1886, at least eighteen cases and four deaths being notified between August 11th and December 4th. The early cases seem to have been mistaken for "scarlatina." In Hartlepool—a town in which the poorer quarters are so crowded together as to render impossible free areation, and the houses described by Mr. Spear, in many cases "so ill-ventilated, damp, and in such bad repair as to be unfit for habitation"—typhus broke out in 1886; the first cases were certainly unrecognised, and were confused with "typhoid," there were 141 known cases, but owing to defects in the administration of Hartlepool at that date only 58 cases were removed to hospital. The same report gives details of typhus outbreaks in Oldham, Maryport, Sunderland, Liverpool, and other places, and Mr. Spear concludes as follows: "The circumstances related above will show how difficult it has been found in the majority of cases to learn the actual origin of an outbreak of typhus. The frequency with which the early cases are mild in character so as to pass unrecognised, and the constancy with which they appear under circumstances of destitution and squalor, may suggest the possibility of the germination or growth under such conditions of a morbific agent possessed of potential capacity, thereafter progressively developing infectiveness and specificity—a theory which, in relation to apparently simple sore throat and diphtheria, has been brought under notice by Dr. Thorne. I have not found, however, that early, apparently initial, cases among adults are exceptionally mild. It seems that this characteristic of early cases is marked because of the frequency with which children are the first to suffer, and they, although it is somewhat paradoxical considering their greater susceptibility to infection, exhibit first to last during the progress of an epidemic singular immunity from severe and fatal attack. Moreover, although the disease amongst children is comparatively benign, it exhibits, so far as my experience goes, marked specific characters. The characteristic measly eruption is commonly distinguishable, and nervous and nutritive disturbances as shown, for example, by subsequent though transient deafness, and the falling off of the hair, which we should not expect to follow an ordinary febrile attack, are of extremely frequent occurrence." The report next lays stress on the frequency of failure to recognise the early cases, and the lamentable results. "In Leeds, Hartlepool, Carlisle,

Middlesborough, Oldham, Newcastle-on-Tyne, and Flint the disease gained a footing through the neglect of unrecognised cases, and in Liverpool this is the common experience with respect to constantly recurring localised outbreaks." . . . The comparative inactivity of the typhus of recent years—its slowness of extension—is, it would appear, mainly attributable to the comparative absence of distress; for, although much harassing poverty has prevailed of late, that form of it has happily been exceptional which amounts to absolute want. That the inherent potency of the infection remains the same may be inferred from the fact that under the more fixed and comparable conditions its behaviour does not vary; it will still spread with great frequency to the well fed and well housed, as, for example, to hospital nurses, when such persons are much exposed to its influence; and again, its fatality amongst adults is maintained. On the other hand, the belief indicated above is supported by observing its constant predilection for the most indigent of the population, by noticing the manner in which it will single out the most distressed and squalid households, and then spread to all the various members." [1]

(305) *The Nazareth House Outbreak.*

The outbreak of typhus at Nazareth House in 1882-3 is particularly instructive to medical officers of health, for it is a good example of the mild form which modern typhus may assume and the necessity of the accurate diagnosis of the febrile ailments of children. Nazareth House is a home in Hammersmith for the succour of the aged poor and destitute children. Its population in 1883 was 53 sisters of charity, 133 old persons, male and female, and 175 children. On October 8th a visit was made by the uncle of one of the children, accompanied by a little child, who had recently recovered from "some illness." The illness of this child, as investigated by Mr. Spear, was probably undiagnosed typhus. The uncle lived in a very bad cellar-dwelling in Hammersmith, he looked himself ill. On the 22nd of October the child E. L., which had been visited, sickened of a feverish disorder, which was thought to be "influenza," the sister who nursed her remembered a measly rash, the child's hair subsequently fell off leaving the

[1] The most recent recorded outbreak of typhus is one which occurred in Sheffield in 1890, and is described by Dr. Thomson. *Public Health*, vol. iii. p. 17.

head almost bald; five weeks after E. L.'s attack, when the latter had been down in the class room for about a fortnight a second child, C. O., was taken ill. Then a child who had sat at C. O.'s bedside reading to her was stricken, so "the disease continued to spread, until on the 9th of January, 1883, eight cases had occurred, all of them, with the exception of the first case, being very slight it appears, so that the disease was still looked upon as "influenza." On January 9th Christmas day was kept; the children had a Christmas tree and a dramatic performance, and in the evening a large party of friends from the outside, as well as the inmates, including the convalescent children, were assembled in the "Community" Hall. Two priests played much with the children on January 9th, and they both afterwards passed through an attack of fever, which was regarded at the time by different medical attendants as typhoid, but which there is great probability was typhus. One sickened exactly fourteen days after the day of the party; the other had been ailing for some days, and the commencement of his attack is not well determined. On the 9th of January two children were poorly at Nazareth House, and one was confined to bed, and on the following day two sickened. One of these last suffered from a lung complication, and died on January 23rd. She was eighteen years of age, and her death was certified as from "influenza, congestion, and convulsions." Meanwhile other cases occurred, so that on February 2nd seven more children were ill. The medical attendant now suspected typhus fever, precautions as to the admission of strangers were prescribed, and a few days later, on February 6th, when a sister who had been nursing the children was attacked, pretty complete isolation measures were adopted.[1]

In all the cases were thirty-one in number. The disease was actually three months prevailing in a mild form before it was recognised, the home itself was neither dirty nor overcrowded, and the sanitary arrangements and regulations were reported by Mr. Spear to be excellent.

(306) *The Isolation and Prevention of Typhus.*

The prevention of typhus is in theory of the simplest:—given good ventilation and ample cubic space typhus disappears. Since

[1] *Report of the Medical Officer to the Local Government Board for* 1883. Mr. Spear's report upon an outbreak of typhus fever at Nazareth House, Hammersmith.

the severe application of the Artisans and Labourers' Dwellings Acts in the parishes of St. Giles and St. Marylebone, and the construction of improved dwellings, typhus has become extinct in those parishes. The improvements in Liverpool have also markedly reduced the disease, and probably in a few years typhus will almost disappear from the mortality records of that city. An outbreak of typhus demands the immediate personal investigation and attention of the health officer. There should be a house-to-house and room-to-room inspection of the affected area, and cases of overcrowding should be rigidly dealt with. Handbills distributed among the people, insisting upon the almost certain prevention of the malady by the windows of sleeping rooms being open at night, may also do good. In such bills it should be specially pointed out that typhus is not so much a children's as an adult's disease, and that therefore individual effort in the way of cleanliness, aeration, and sobriety is the more essential. In dealing with Irish populations the hearty co-operation of the priest will make the work of the health officer easier, and should always be obtained if possible. Every case of illness, no matter under what name it is called, should be investigated by the health officer in the affected area. In the first few cases of typhus the diagnosis must be well established; but if the outbreak seems to be likely to attain any dimensions, it is not wise to wait for the eruption, but given an adult with headache, high fever, and prostration, he should be removed at once.

The danger of infection to the medical men and nurses of hospitals in which typhus is treated, as well as to laundresses who wash typhus-infected linen, is considerable: the records of the London Fever Hospital give lamentable evidence of this. No doubt some of the exposure might be rendered less dangerous; for instance, if a constant current of air could be established in a typhus ward it should not be difficult for nurses and doctors to do all that is necessary in the way of attention and examination on the windward side. Auscultation is specially dangerous, the more so if the clothes are turned down and the physician immediately puts his ear to the usual short stethoscope. It is to be recommended that the chest to be examined remain exposed for some minutes previously to the air, and that the long flexible stethoscope be always used. Nurses should be preferably selected above thirty-

five years of age; they should be sufficient in number so as not to be fatigued, and be carefully instructed as to the danger of breathing too closely the emanations from the patient. The most ample ventilation should be enforced, and the greatest cubic space possible is a necessity in the treatment of typhus patients. It is not known whether the excreta from bowels and kidneys are infectious or not, but it is prudent to consider them so, and, as in typhoid fever, to receive them in disinfecting solutions.

The ordinary disinfection and aeration of rooms from which typhus patients have been removed is sufficient, for however virulent the typhus poison in its concentrated state may be, there is ample proof of its easy destruction. Fumigation with sulphur or chlorine and afterwards submitting bedding and other things to a heat above the temperature of boiling water for a few hours, will perfectly disinfect.

Experience derived from Liverpool and other places show the necessity of having "houses of refuge" provided, in which those persons who have been, so to speak, soaking in a typhus atmosphere, although not themselves suffering from the disease, can be purified and have their clothes disinfected.

CHAPTER XXVII.

MICRO-PARASITIC DISEASES AFFECTING THE NERVOUS SYSTEM.—RABIES.—TETANUS.—WHOOPING COUGH.

(307) *Rabies.*

To this group belong rabies, tetanus, and whooping cough.

It is unnecessary to treat of rabies in this work, for it is more a matter of veterinary police. It is obvious that, so far as danger to man is concerned, a malady that is implanted only by direct inoculation by the bite of an animal (usually a dog) can be practically suppressed by a general muzzling order throughout the kingdom, carried out with the greatest severity and uniformity for two months. If this were done it is not likely that the order would have to be repeated for several years. This however requires a special Act of Parliament, the present law allowing each county authority to make their own regulations, hence neither uniformity of repression nor permanent good has followed; the unmuzzled rabid dogs of a county not under order biting the muzzled dogs of another.

The beautiful researches of M. Pasteur, showing that the microbe is primarily localized in the nervous system, and that it is possible to attenuate the virus and to perform a protective inoculation even after the bite, are matters of notoriety.

TETANUS.

(308) *Researches on the Bacteriology of Tetanus.*

Tetanus is a disease caused by a micro-parasite; the micro-parasite most frequently enters the body by means of a wound.

It is only within the last few years that the true nature of tetanus has been manifested; the following is a brief notice of the more important researches:—

Carle and Rattone[1] were the first to produce typical tetanus in the rabbit. They inoculated an emulsion of the sciatic nerve from a person who had died of tetanus; infection of a second animal with the sciatic nerve of the first produced the same result, but inoculations of the blood were fruitless.

Nicolaier,[2] under the direction of Flugge, introduced garden earth subcutaneously into rabbits, guinea-pigs, and mice; clonic spasms of the affected limb were produced, and in the course of twenty-four hours this was followed by general tetanus. At the seat of inoculation fine bristle-shaped bacilli were found; these were often swollen at one end. If the garden earth was previously sterilized by heating it to 110°, then no effect followed; artificial cultures were not pathogenic. Winiwarter[3] repeated and confirmed these results.

Rosenbach was the first who discovered the bacillus in man. He injected under the skin of guinea-pigs and rabbits pieces of tissue taken from the boundary-line between the sound and gangrenous parts of the thigh of a man dying of tetanus; tetanus was produced in the animals, and it was propagated through a series of animals by inoculation of matters taken from near the inoculated place. The bacillus was recognized in the neighbourhood of the inoculation, but not in the rest of the organs.

Brieger[4] separated a ptomaine from an impure culture of the bacillus; he called this substance tetanin, because it produced, even if injected in minute quantity, tetanus in animals. He separated the same substance from the amputated arm of a tetanic subject.

Bonome[5] in three cases of traumatic tetanus propagated the malady from matter taken from the neighbourhood of the wounds, and recognized the bacillus; his inoculations of the blood, the spinal marrow, and the nervous tissues were negative. He found

[1] Carle e Rattone, "Studio experimentale sull' eziologia del tetano," *Giornale della R. Acad. di Med. di Torino*, 1884, 3.
[2] Nicolaier, *Deutsche med. Wochenschrift*, 1884, 2.
[3] Winiwarter, *Allgemeine chirurg. Pathologie u. Therapie*, 1817, 13te auflage.
[4] Brieger, *Berlin. klin. Wochenschrift*, 1887, 15, 17; 1888, 17.
[5] Bonome, *Giornale della R. Acad. di Med. di Torino*, 1886. *Archiv par. la Scienza Med.* 1888, xii. 4.

that the bacillus when in the spore state was not destroyed at a temperature of 100°. He made the instructive observation that at the storming of the church in Bajaido, out of seventy wounded, nine died of tetanus, and in three he recognized the specific bacillus. He experimented with limestone dust taken from the ruins; this inoculated into wounds produced tetanus in animals, and he found in the pus taken from the inoculated part the bacillus. The researches of Giordano,[1] Ferrari,[2] and Hochsinger[3] are also to be mentioned, from all of which the conclusion may be drawn that traumatic tetanus has usually some connection with the contamination of wounds by earth. This connection was specially clear in some cases observed by Beumer. One of these cases was that of a man, aged thirty-one, who was attacked with tetanus after a wound by a splinter when playing at skittles, and it was found that small splinters of wood taken from the skittle alley produced tetanus when inserted beneath the skin of animals. In a second case, recorded by the same observer, a boy running barefoot wounded his foot by a stone, and tetanus followed; small stones taken from the same place introduced into wounds in animals produced tetanus.

In a later series of experiments,[4] Beumer excised little bits of tissue from the neighbourhood of the umbilicus of infants dying from *tetanus neonatorum*, and inoculated these bits of tissue into animals and produced tetanus.

Beumer also proved, through a highly exact series of researches, that the tetanus-producing bacillus was very widely distributed in the superficial layers of various kinds of soil, on the foul surface of streets, and in the dust of dwellings. He also showed that a wound when actively granulating was not very susceptible of taking the infection.

Several cases are on record in which tetanus seems to have been conveyed by the hands or instruments of the surgeon. One of the most striking of these is related by Langer, in which the horses castrated by the same *écraseur* died of tetanus, but after boiling the instrument in oil no others died or were affected from its use.

[1] Giordano, *Giornale dell. Acad. di Med. di Torino*, 1887, 3, 4.
[2] Ferrari, *Italien. Chirurg. Congress, Genua*, April, 1887.
[3] Hochsinger, *Centralblatt f. Bacteriol.* 1887, ii. 2, 3.
[4] Beumer, *Berlin, klin. Wochenschrift*, 1887, 30, 31.

The latest observations and experiments have been made by Eiselsberg.[1] He has given details of six cases which he has had the opportunity of investigating.

The first case was that of a woman with a compound fracture; the wound had been much contaminated by dirt; tetanus occurred on the fourteenth day. Cultures were made from the blood, with negative results. Eiselsberg also inoculated the blood into animals, but no effect followed, nor could any bacilli be found therein; on the other hand, the secretion from the wound contained, with other organisms, the specific bacillus, and from this secretion impure cultures were obtained. A culture of the third generation was injected into three rabbits and four mice; the mice died the following day, one rabbit remained healthy, the second suffered from tetanus and recovered, the third died of tetanus.

The second case was that of a man who had a mild attack after an injury to his finger; in this case there was also contamination of the wound by dirt. Experiments gave negative results.

The third case was that of a man who died from tetanus. Small pieces of skin taken from near the wound produced tetanus in animals. Impure cultures of the wound-secretion produced the same effects.

A fourth case gave very similar results. In this case the man had received his wound in a certain cellar, and experiments were made on the earth of this cellar; tetanus was produced when the wounds of animals were contaminated with it.

In the fifth case tetanus had been produced by a splinter of wood. The splinter had been carefully preserved by the man's wife for two and a half years. Small pieces of this splinter were inserted beneath the skin of animals, and tetanus followed. The bacillus was recognized in the secretion.

In the sixth case a servant in scrubbing a floor got a splinter of the wood of the floor under her thumb-nail and died of tetanus. Fourteen months after the same splinter produced tetanus in rabbits. So far as to traumatic tetanus. Idiopathic tetanus is rare, and it is not improbable that in reality it does not exist, but is derived from some slight scratch or wound which has passed unnoticed; in other words, so-called idiopathic tetanus has a concealed traumatic origin.

[1] *Wiener klin. Wochenschrift*, 1888. *Public Health*, vol. i. 117.

(309) *The Prevention of Tetanus.*

In view of the modern discovery that tetanus is produced by a micro-organism to be found in dust and dirt and adhering to foreign substances, the surgeon will naturally take the greatest pains not alone to cleanse wounds but to apply to the cut surfaces in cases of foul wounds strong disinfectants, or even where necessary cut clean away the bruised and soiled cut surfaces. It is, however, obvious that save in the way of disseminating information on these points among the public at large, tetanus is a malady against which the Health Officer can do little or nothing. He may however point out that the discharges from such wounds, should be collected on clean rags or similar substances, which can be either disinfected or burned.

WHOOPING-COUGH.

(310) *General Nature of Whooping-Cough.*

Whooping-cough is believed to be a micro-parasitic disease, the poison of which more especially affects the nervous system. With a few exceptions the sufferers are solely children and persons of tender years. The most prominent symptom is a peculiar expiratory cough, by which the lungs are pretty well emptied of air; following this cough there is a prolonged inspiration with a peculiar crowing sound—the so-called "whoop."

(311) *Statistics.*

Whooping-cough kills a large number of children, the mean number of yearly deaths during the twenty-five years ending 1888 was 11,964; the maximum number occurred in 1878, when 17,784 deaths were ascribed to this cause, the minimum in 1864, 8,570 deaths.

(312) *Etiology.*

Fatal and common disease as whooping-cough is, there is very little definite knowledge concerning the laws which govern its diffusion. All that is known is that it is excessively infectious, and that once introduced into a house, it is liable to attack all young children not protected by a previous attack. In its

seasonal distribution it is most fatal in January, February, and March, up to the second week of April. A curve plotted out for a number of years showing the weekly deaths from whooping-cough shows an inverse relation to the scarlet fever curve; that is to say, the latter curve turned upside down is like that of whooping-cough, the maximum of the one corresponding with the minimum of the other. Whether there is any real antagonism between these two diseases is not known.

The disease has a stage of latency, which is generally put at between five or six days.

The infecting distance is great. An instance occurred under the writer's own observation in which a tramp brought a child from some distance into a small town in Somersetshire to the workhouse. At the time there was no whooping-cough in town or workhouse. The child had whooping-cough. The woman with her baby was allowed to sit at a table in the open air, at which the workhouse children were having a sort of treat. The woman remained there about an hour. In a few days a third of the workhouse children were simultaneously affected with whooping-cough.

The well known St. Helena case may also be cited. The captain of a ship in which there was some children suffering from whooping-cough allowed the linen of the sick to be sent ashore, and shortly afterwards the same disease broke out among the inhabitants. Burger[1] has stated that elliptical cocci are constantly present in the sputum of persons affected with whooping-cough, but the bacteriology has not been worked out.

(313) *Duty of the Medical Officer of Health.*

In cases of whooping-cough it is certain that on recovery or death the clothing, and the room with its contents, should be properly disinfected. Hitherto it has not been practicable to isolate cases of whooping-cough in special hospitals.

[1] *Berl. klin. Wochenschrift*, 1883.

CHAPTER XXVIII.

MICRO-PARASITIC DISEASES MAINLY AFFECTING THE RESPIRATORY ORGANS.

PNEUMONIA.

(314) *Epidemic Pneumonia.*

THERE is abundant evidence that at least the species of pneumonia, known as "croupous or fibrinous pneumonia," is one of the class of maladies produced by a micro-parasite. It is infectious, and not unfrequently prevails in an epidemic form. This is the view generally adopted by hygienists, and one which the writer has held and taught for the last twelve or thirteen years; the profession at large have not yet fully adopted this view, hence few, if any, precautions are taken to prevent the spread of the disease.

(315) *Evidence of the Infectious Character of Pneumonia.*

It may be well here to adduce some evidence of the infectious character of pneumonia.

In the Akerhus prison [1] two outbreaks occurred, one in 1847, another in 1866. In the last epidemic no less than sixty-two cases occurred in six months amongst 360 prisoners.

Thoresen, of Eidswold,[2] records an epidemic of croupous pneumonia almost confined to a single row of cottages. The epidemic lasted a month.

An epidemic broke out in 1860 in the Mediterranean fleet. Its infective character was very evident, and Dr. Bryson,[3] who recorded

[1] Norsk. *Mag* f. *Laegevidenskaben,* vol. xxii., p. 345.
[2] *Ibid.* 3rd ser., vol. i., p. 65, 1871.
[3] *Lancet,* January 9, 1862.

it, pointed out several characters common to it, and the pleuro-pneumonia of cattle.

Five cases of pneumonia[1] occurred almost simultaneously, March 1874, at a school at East Sheen, Mortlake. The time of attack coincided with a large escape of sewer gas into the school, and the boy first attacked slept in one of the rooms most exposed to the effluvium.

Mr. Alfred Mayo[2] communicated cases of infectious pneumonia to the author as follows. The first case was that of a bricklayer, aged thirty-five, who was taken ill with pleuro-pneumonia. His mother nursed him and caught the malady and died. A neighbour nursed this last case. She, in her turn, caught the disease and died. Lastly, her child took it but recovered.

In the writer's *Dictionary of Hygiene*, the following additional cases are recorded:—

A farmer at Bow, Devon, suffered from pneumonia; his niece nursed him; she soon became affected with the same disorder, and, going home, infected her husband.

A Dolton farmer became ill with pneumonia on April 16th, 1875, and died on the 18th. The servant girl who nursed him suffered from the same malady, the first symptoms appearing a week after the death. She went whilst ill to her married sister's home, who also contracted the same malady.

Another man became ill of pneumonia in April of the same year, and died after ten days' illness. His wife contracted the disease, her first symptoms appearing immediately after his death.

About the same date, a farmer's daughter, a mile from the house of the former patient, became ill of pneumonia; five other cases followed, all in the same parish (population, 470), consisting of a small village and a few scattered houses.

A clergyman became ill with acute pneumonia. The woman who nursed him in about seven days contracted the same disease. The clergyman's sister, taking the place of the nurse was, in her turn, also seized with pneumonia. A brother of the clergyman now took the place of the last; he, in his turn, also was laid up with the same disease. The nurse and sister both died, the two brothers recovered.

[1] "Sewer Gas Pneumonia." *Irish Hospital Gazette*, Nov. 1, 1874.
[2] Article "Pneumonia" in *Dictionary of Hygiene*, London, 1876.

(316) *The Middlesborough Epidemic.*

To these examples may be added the Middlesborough epidemic,[1] investigated by Dr. Ballard. Middlesborough itself has a population of about 69,000, and the adjacent sanitary districts of Ormesby, Normanby, and Eston, are something in the aggregate about 28,000. The epidemic period extended over twenty-four weeks from January 20th to July 14th, 1888, during which time there were 369 fatal cases of pneumonia; this, probably, represented some 1,000 cases, for the mortality of 762 known cases was 23·1 per cent. There was an exceptional mortality among males, and an exceptional incidence on certain age periods. On each 10,000 males the incidence was 64, on each 10,000 females, 16. The rate of mortality in the group under 15 years of age was about the average, but above 15 about 5 times that of the mean annual mortality for corresponding periods. In the age group, 15 to 45 years, the rate of the mortality was 4·6 times that of the mean of eight years, and at ages above 45 it was 5·4 times that of the mean. Dr. Ballard gives a clear account of the symptoms, and also of the post-mortem appearances, these differ but little from the acute pleuro-pneumonia that any one who has practised in rural districts is quite familiar with. There was ample evidence of its infective character.

(317) *Etiology of Pneumonia. Gamaléia's Views.*

Gamaléia[2] has carefully worked out the bacteriology of pneumonia, and his views are as follows:—

He considers that the *streptococcus lanceolatus* is the cause of pneumonia. This same micro-organism under the name of the diplococcus lanceolatus is, according to Professor Pio Poa and Dr. Guido Bordoni Ufferduzzi, the cause of epidemic cerebro-spinal meningitis (see *Public Health*, vol. i. p. 85). Its presence is constant in pneumonia. This is proved not alone from the clinical experience of others, but from his own observations on twelve autopsies. "I have studied," says Gamaléia, "these post mortems

[1] *Supplement to Eighteenth Annual Report of the Local Government Board*, 1888-89.

[2] "The Etiology of Fibrinous Pneumonia in Man." by N. M. Gamaléia. (*Annales de l'Institut Pasteur.* No. 8, August, 1888.) *Public Health*, vol. ii.

without choice, and in the order in which they presented themselves on the dissecting table. Some cases had been erroneously diagnosed as those of typhoid fever or miliary tuberculosis, but I only accepted the diagnosis revealed by the corpse. Thus I have collected varied forms of pneumonia—simple pneumonia of a single lobe, double pneumonia, pneumonia complicated with cerebro-spinal meningitis and endocarditis. The duration of the malady was also variable, and I had under observation the different anatomical forms of the sick lung, the initial hyperæmia, the red hepatisation, grey hepatisation, and abscess. Each case has served me—

"(*a*) To make cultures on gelatin.

"(*b*) To make stained microscopical preparations of the juice of different organs.

"(*c*) To inoculate animals sensible to the pneumonic virus.

"The first method rarely succeeded, because the autopsies were made long after death, and the culture of our microbe on solid media is very difficult. A small number of foreign germs prevents the specific culture. The second process has on the contrary always given me positive results, and I have always been able to recognize as cause of the evil the *streptococcus lanceolatus*, that is to say the double lanceolate coccus surrounded by a clear or coloured coccus, retaining the violet coloration of Gram. But on this subject there are important remarks to make. The lanceolate coccus has not always its typical form and aspect. It sometimes happens that in a rabbit or mouse dead of septic pneumonia that the microbes in the blood and even in the spleen present themselves under the form of simple cocci without capsule, whilst the liver and kidneys are full of typical diplococci. Nevertheless, it has only happened to me in three lungs out of the twelve not to find typical forms, but even in these the specific microbe appeared with all its distinctive characters in other parts of the same body (fibrinous pleuritic exudation, spleen, dura mater of spinal cord). Besides, in the human lung (likewise in the sheep), the pneumonic coccus has often its capsule coloured, and as this coloured capsule may be elongated and tortuous, it singularly disfigures the appearance of the microbe. On the contrary, the cocci absorbed by the leucocytes, as is the rule in the first period of the pneumonic affection in the man and the dog often remain as colourless as their

capsules, and are only distinguished as little regular vacuoles in the bodies of cells. Lastly, the same thing may happen which has been observed in the spleen in anthrax, and especially in the œdema of anthrax—that is, the soluble products excreted by the virulent microbes render every preparation too confused to allow the typical form of the microbe to be distinguished. This may be remedied by washing the preparation with alcohol after passing it through the flame.

"These reserves made, I affirm I have always seen the microbe of Pasteur in the pneumonic corpse."

Gamaléia next speaks of the success of his inoculations. He finds the mouse more sensitive than the rabbit. The mouse "inoculated under the skin with an emulsion of pneumonic sputa, dies in twenty-two hours, and presents at the autopsy a mass of typical microbes in the blood and organs." He next deals with the objection made against the etiological unity of fibrinous pneumonia, especially on behalf of Friedlander's microbe. This last microbe is found normally in saliva. It is a good saprophyte, and invades sometimes the diseased or dead lung. Weichselbaum found it in 70 per cent. of his cases, but, with the exception of three cases, always mixed with other microbes. As to the researches of authors preceding Frankel, it is certain the microbe they called Friedlander, which they found, was no other than that of Pasteur, since it was stained by the method of Gram which decolourises the bacillus of Friedlander. As to the experimental production of pneumonia by cultures of Friedlander's microbe, there is no doubt several bacteria will produce pneumonia. Such for instance which determine at the seat of inoculation a sero-fibrinous exudation, as the microbe of fowl cholera, and the bacteria of charbon.

(318) *Pathogenic Rôle of the Streptococcus Lanceolatus.*

Contrary to general belief, this microbe does produce typical pneumonia in the dog and sheep. The experiments which follow were made with virulent pneumonic virus, that is with the Pasteur microbe taken from the human corpse, or isolated from pneumonic sputa, and its virulence increased by several passages through rabbits. The successive passages through the organism of the rabbit, especially if the inoculation has been intravenous, augments

manifestly the virulence of the pneumonic streptococcus. The time elapsing between infection and death becomes progressively shorter from twenty-four hours to twelve, and even to five hours. The character of the disease is also changed; instead of the prolonged febrile affection with meningitic complications, produced by the ordinary virus, a sort of poisoning appears, which commences with the infection, and leads to a tranquil death, preceded by a progressive and continuous loss of strength. This excessively virulent matter no longer leaves in the body the hyperæmia and hypertrophy of the spleen typical of the ordinary virus—the animal succumbs without resisting. The blood of the heart is full of streptococci which have in this case often coloured capsules. It is this blood, or cultures from it, with which the experiments were made.

Animals may be placed in relation to their resistance to the pneumonic virus, on a scale, the bottom of which is occupied by the pigeon with its absolute resistance, and the successive stages by the dog, the sheep, and the rat; the rabbit and the mouse are at the top of the scale. The mouse is the animal most sensitive to pneumonia, it always dies after a subcutaneous injection of a few drops of a virulent culture within an interval of from twelve to twenty-four hours, with all the symptoms of subacute septicæmia. At the autopsy is found a slight gelatinous œdema at the seat of inoculation, the spleen more or less hyperæmic, and an enormous quantity of microbes in the blood and in all the organs. The virulence of the microbe increases in its passage through the body of the animal. M. Gamaléia's experiments were made on thirty mice. The disease in the rabbit has the same characters, The *attenuated* virus produces a fibrino-granulous infiltration at the seat of inoculation, a pneumonia, a sero-fibrinous pleurisy with fibrinous peritonitis. The virus sterilized by heat (120° C.), produces a persistent granular tumour which has no tendency to be absorbed. The same tumour is produced by the virulent virus in the rabbit rendered refractory to the virus. The virulence is considerably increased by passing through the rabbit; Gamaléia has made as many as twenty-four transmissions from animal to animal, and has caused pneumonia in 200 rabbits.

The white and grey rat are also very sensitive, and similar lesions are found, but the local effect is greater. The sheep is

more refractory, and requires large doses; here again, the local symptoms are considerable. Death takes place in from the third to the fifth day of the disease. Gamaléia has experimented on twelve dogs. The dog is still more refractory, he is cured generally in from ten to fifteen days, after having passed through all the stages of red and grey hepatisation as in man. The squirrel and the cat occupy in the scale of susceptibility an intermediate place between the rabbit and the rat. All these facts lead to the following conclusion :—

(1) There exists variable degrees of receptivity for the pneumonic virus. These degrees may be measured by the abundance of the microbes of the blood and by the extent of the local reaction. The less an animal resists, the less the inflammatory pneumonia at the place of inoculation, the greater the abundance of microbes in the blood of the corpse. The type of the local reaction varies according to the degree of receptivity. The local reaction absent in the mouse, becomes a restricted hæmorrhagic œdema in the rabbit; the rat presents an extended œdema of a yellow amber tint, and gelatinous consistence; in the sheep and the dog, the œdema is greater, and is composed of sero-fibrinous parts mixed with harder granulations having a grey tint constituted by an abundant cellular infiltration.

(2) The animals little sensitive to the pneumonic virus offer a very pronounced local resistance, followed by a typical fibrinous pneumonia. Pneumonia, then, is not a general infection localizing itself in the lung as its place of predilection, but the local reaction has the place of the virulent inoculation. The animals extremely susceptible, as the rabbit, and mouse, have no pneumonia because there is no local action, and the virus generalizes itself within them and slays them by acute septicæmia.

(3) Man belongs, in relation to the pneumonic virus, to the category of resistant animals. Hence the feeble mortality from pneumonia (10·8 per cent.)—hence the extended local reaction in the form of inflammation of the lungs, and the paucity of microbes in his blood. It is clear that the results obtained in the dog and sheep, animals little susceptible, are specially applicable to the elucidation of human pathology. It may be affirmed that an inoculation into the pulmonary tissue of animals partially refractory (*e.g.*, dogs, sheep) of the *streptococcus lanceolatus*,

gives rise to a typical fibrinous pneumonia. Thus the chief objection advanced against the etiological *rolc* of this microbe falls to the ground.

(319) *Streptococcus Lanceolatus in Healthy Persons.*

How is the fact to be explained that the *streptococcus lanceolatus* is found in the saliva of healthy persons? It is necessary to at once admit its frequent presence in normal saliva. Two cases in which Gamaléia found it most abundant were in the saliva of persons not suffering from pneumonia. Goldenberg has found the microbe in more than half the mouth secretions of healthy persons.

M. Pasteur has, a long time ago, shown that a disease of silkworms is caused by a common microbe which is found everywhere in the food of the worms, remaining inoffensive for those who have good digestion, and slaying those in feeble health or with weak digestive organs. M. Pasteur has also shown that the septic vibrio, a very virulent microbe, always exists in the intestines of the mammalia without troubling their health.

Gamaléia himself has found that the microbe of fowl cholera, so terrible for birds, is constantly found, although in small numbers, in their intestines, and that a poisoning by non-pathogenic bacteria suffices to open for them a portal into the blood.

It may, then, be believed that among healthy persons the *streptococcus lanceolatus* finds conditions opposed to its hurtful action. These conditions are only realised among animals little susceptible, as man, the sheep, and the dog; for the others, like rabbits and mice, succumb to the inhalation of the virus. Gamaléia has instituted direct experiments on this point. Whilst the virulent streptococcus introduced into the lung parenchyma of sheep always develops there a fatal fibrinous pneumonia, the same virus injected by the trachea does not kill. Thus, on more than twenty sheep, virulent pneumonic virus, injected into the trachea in quantities of 10 c.c., did not kill one. Hence it must be concluded that a lesion of the lung parenchyma, and an introduction of the virus into this wounded parenchyma, are necessary conditions for the production of pneumonia in sheep. It was interesting to know the more intimate facts which pass after

intrabronchial injection. Gamaléia made the following experiment to elucidate this :—

On May 11th, at nine a.m., three sheep were inoculated by intrabronchial injection with the virulent streptococcus. Body temperature before infection 40°—40·5 C., at seven p.m. 40·2 to 40·5. The first was killed in the evening. Autopsy, spleen soft and hyperæmic ; in both lungs and particularly at the apex of the right lung, regions very hyperæmic. The microscopical examination of this region revealed the presence of the streptococcus as well as an infiltration of mononuclear and polynuclear cells. These two varieties of " phagocytes " contained masses of Pasteur's microbe. Free streptococci were rare. A mouse inoculated by the juice of the hyperæmic lung succumbed the next day to septicæmic pneumonia ; some streptococci were found in the spleen, and in the disintegrated state (*à l'état digéré*), in the liver, and particularly in the kidneys.

On May 12th, at three p.m., the surviving sheep had a temperature of 39·6° and 39·2°. One was killed. The autopsy showed catarrh of the bronchial tubes ; the walls of the tubes were hyperæmic and covered with rusty-coloured mucus (the injection was made from the blood of a *lapin de passage*). There were hyperæmic spots on the right lung. A microscopical examination showed the absence of the typical streptococcus in the lung. A squirrel inoculated by the pulmonary juice did not take pneumonia. The streptococcus, on the contrary, was abundant in the bronchial mucus, mixed, however, with other microbes, one of which was similar to that of Friedlander's microbe.

It is thus seen that the pneumonic virus, introduced into the trachea, does not determine the lesions of pneumonia in the healthy lung. It provokes a pulmonary hyperæmia and afflux of phagocytes which destroy the streptococcus. A few microbes pass into the blood, from whence they are eliminated in the ordinary way. But neither in the pulmonary alveoli nor in the capillaries are conditions found sufficient for the production of the pneumonic exudation. Microbes which are disintegrated or digested in the pulmonary alveoli and in the blood remain living in the bronchial mucus, and may, under favourable conditions, conduce to the development of pneumonia.

This is what happened indeed to the third sheep of the preceding

experiment. After remaining quite well during the experiment, it was inoculated in the eye by the virus of rabies, and succumbed on June 4th. The autopsy showed typical lesions of croupous pneumonia. The left lung was covered with a thick fibrinous layer of a gray colour, and was augmented in volume, and had all the other signs of pneumonia with fibrinous exudation, the pneumonic streptococcus was found in great number; the streptococcus was less numerous in the hepatised red and gray lung tissue, and was infrequent in the spleen and liver.

To better study the mechanism of immunity of healthy lungs, a microscopical analysis was made of the sputa of a subject who suffered from fibrinous pneumonia, and afterwards from chronic bronchitis; this subject expectorated masses of microbes, virulent to rabbits.

The sputum was tenacious, and adhered to the vessel; under the microscope it showed itself as a nearly pure culture of the specific streptococcus, with polynuclear globules, and endothelial cells, having a large nucleus and very granular. An attentive examination of these last cells, which have all the character of "macrophages," showed that they contained enormous numbers of the streptococcus of Pasteur in different phases of degradation. In the same cell with the typical form of the diplococcus may be found attenuated and angular forms which comparison alone connects with the specific microbe. One may in this way be convinced that the débris contained in the "macrophages" are the remnants of pneumonic microbes. The polynuclear leucocytes also contain the streptococcus but in much smaller quantity.

These phenomena give us the sought-for explanation of the immunity of the pulmonary tissue; the pathogenic microbes, even when they exist in very great quantity in the bronchial mucus, and arrive at the pulmonary alveoli, are stopped in their development by the macrophages who seize and devour them. In this strife the endothelial cells may themselves die and be rejected in the sputum. It is then clear that the production of pneumonia, or the maintenance of health, depends on the relative activity of the two orders of combatants. It may be also comprehended how the issue of the strife may be determined by slight predisposing causes, as cold, bronchitis, a fall, contusion of the chest, inhalation of irritating vapours and others.

In this way is explicable why the etiology of fibrinous pneumonia is composed of two factors—contagion, and the influence of the seasons with their action on the pulmonary cells.

To verify this Gamaléia has experimented on the pneumonic infection by first injecting substances capable of slaying the pulmonary "macrophages." Into the tracheas of six sheep was injected a solution of tartar emetic, four of them being inoculated, also by the trachea, with the pneumonic virus. One died the next morning from the inoculation, and the autopsy presented red hepatisation of the right lung in several places; a second had typical pneumonia, the third and fourth suffered from fever; "*the control animals*" remained healthy.

Hence we may conclude that influences injurious to the pulmonary cells predispose to the development of the streptococcus in the lung.

The conclusions that Gamaléia finally draws are:—That the *streptococcus lanceolatus Pasteuri* is always found in human fibrinous pneumonia. That this streptococcus produces in partially refractory animals fibrinous inflammation of the lungs. That its pathogenic influence is held in check in healthy men by the activity of the pulmonary phagocytes. He believes he has shown that human fibrous pneumonia is always caused by Pasteur's microbe.

(320) *Bacteriology of the Middlesborough Pneumonia Cases.*

Dr. Klein[1] has made a careful research by the aid of modern methods on the micro-organisms in the cases of pneumonia in the outbreak recorded by Dr. Ballard (p. 416), and he draws the following conclusions:—

(1) In the diseased lung of the Middlesborough pneumonia cases there were present in large numbers short bacilli, that are not Friedländer's bacillus nor the *Diplococcus pneumoniæ* of Frankel and Weichselbaum, but which upon cultivation and inoculation into rodents appear to be a definite species, distinctly different from either: he therefore calls this bacillus the *Bacillus Pneumoniæ*.

(2) Neither Friedländer's bacillus nor the *Diplococcus pneumoniæ*

[1] *Supplement to the Eighteenth Annual Report of the Local Government Board*, 1888–89, 323.

of Frankel and Weichselbaum was obtainable from this human pneumonic lung by cultivation.

(3) The lung-juice of this pneumonia when inoculated into guinea-pigs, and especially when inoculated into mice, produced an acute disease, of which the chief and constant anatomical lesion was severe inflammation of the lungs. Mice were more susceptible than guinea-pigs.

(4) Artificial cultures of the *Bacillus pneumoniæ* from the human lung or from the blood of an experimental mouse proved very virulent to mice—less so to guinea-pigs. In mice these bacilli produced the same fatal disease as mentioned above, with conspicuous pneumonia.

(5) The blood and lung juice of mice and of guinea-pigs dead of the disease experimentally induced by the materials from the severally above recorded sources, produced on inoculation into other mice and guinea-pigs severe fatal pneumonia.

(6) In all experimental animals dead of the induced disease, the lung-juice (in mice also as a rule the heart's blood and the spleen), contained the *bacillus pneumoniæ.*

(7) By feeding mice with artificial cultures of the bacillus, the same pneumonia was produced, but not in so large a proportion of experimental animals as by inoculation.

(321) *Preventive Measures.*

Whether Gamaléia's views on pneumonia are correct or whether they will be modified by future research, there is good reason to class epidemic pneumonia as dependent upon sanitary state, and intimately connected with foul sewers, collections of filth and general air and soil pollution. It will be the duty of the health officer to inquire into cases of pneumonia as he would into any other septic disease, to enforce isolation where he can, and also to cause disinfection of the room, bedding and clothing after the termination of each case.

CHAPTER XXIX.

SEPTICÆMIC MALADIES.

ERYSIPELAS.

ERYSIPELAS is a septic disease closely allied to some forms of diphtheria, to puerperal fever, and to pyæmia. It has also an analogy to scarlet fever.

Erysipelas is a contagious and infectious disease, the common external sign of which is an inflammation of the integument, extending in some cases to the areolar tissue, and tending to spread indefinitely.

(322) *Mortality from Erysipelas.*

During the twenty-five years ending 1886, 51,582 deaths in England and Wales are ascribed to this cause; the maximum number of deaths was in 1874, when 3,358 deaths were registered; the minimum number was in 1886, when 1,523 deaths were caused by erysipelas; the mean number of the whole being 2,063.

Erysipelas is one of the diseases to be certified by the medical man or notified by the householder in places like the metropolis, where the Infectious Disease Notification Act is in force, so that in a few years there will be valuable statistical evidence as to the frequency of illness from this malady.

Erysipelas attacks more males than females, the cause is probably because males have more frequently external wounds and abrasions than females.

(323) *Mortality as Influenced by Season.*

The deaths from erysipelas are above the average from the middle of September to the end of March, and below the average for the rest of the year. The deaths rise rapidly from the last week in October to the third week of November, when the absolute maximum for the year is attained. The minimum period is from the middle of June to that of September (Mitchell and Buchan). If the deaths from erysipelas and those from puerperal fever be plotted out for a sufficient number of years in a curve according to season, the curves very fairly coincide.

(324) *Bacteriology.*

Erysipelas is without doubt caused by a micro-organism. This has been named the *streptococcus erysipelatosus;* it is found at the edge of the inflamed skin, occupying the lymphatic channels and spreading along them as the disease advances. The cocci are from ·3 μ to ·4 μ in diameter; they have been cultivated outside the body and from the artificial cultures; true erysipelas in such animals as the rabbit has been induced by inoculation.

Fehleisen[1] carefully examined thirteen cases of erysipelas, he found identical changes in all. The lymph vessels of the skin as well as those of the subcutaneous cellular tissue, but more especially those of the most superficial layer of the corium were found packed with chain micrococci. In those places in which a particularly great development of the cocci had taken place they were found lying in the lymph spaces and channels of the skin. They never entered the blood-vessels.

(325) *Etiology.*

By far the most usual means of infection is by a wound, and it may be that many cases of idiopathic erysipelas are also due to an entry of the microbe by means of some superficial and unnoticed abrasion.

All the older hospitals have their histories of erysipelas. In 1760, for example, erysipelas spread so extensively through the

[1] Fehleisen *On Erysipelas,* translated by L. Ogilvie, M.B., B.Sc., London, 1886.

wards of St. Thomas's Hospital, as to excite the greatest alarm. No modern surgeon would allow a case of erysipelas to be in the same ward as other patients who have either undergone or are about to undergo operations.

In the winter of 1851 erysipelas broke out in one of the wards of University College Hospital, and is thus described by Mr. Erichsen: "The hospital had been free from any cases of this kind for a considerable time, when on the 15th of January, at about noon, a man was admitted under my care and placed in Brundrett Ward. On my visit, two hours after his admission, I ordered him to be removed to a separate room, and directed the chlorides to be freely used in the ward from which he had been taken. Notwithstanding these precautions, two days after this a patient from whom a necrosed portion of ilium had been removed a few weeks previously, and who was lying in the adjoining bed to that in which the patient with the erysipelas had been temporarily placed, was seized with erysipelas of which he speedily died. The disease then spread to almost every case in the ward, and proved fatal to several persons who had been recently operated upon."

Quite independent of wounds there are a number of cases on record in which persons in contact with cases of erysipelas have been affected, and the inference seems a fair one that they took the disease through the lungs.

The incubation period when erysipelas is inoculated varies from fifteen to sixty hours.

(326) *Disinfection after Erysipelas.*

It has been found very difficult in certain cases to destroy the contagion of erysipelas. For example, the old *Dreadnought* was so saturated with it, that it was found necessary to cease using it as a hospital ship. Hence a hospital ward which has had cases of erysipelas should be treated in a most rigorous manner. After a thorough and complete cleansing, it should be well fumigated with chlorine, and then every part wetted with a solution of corrosive sublimate 1 per 1,000. Erysipelas is, however, thanks to the new antiseptic surgery, becoming rare in hospitals. When the disease occurs in private houses the ordinary means of

disinfection will suffice. In investigating an epidemic of erysipelas particular attention should be paid to the drainage and to the abatement of nuisances, for it is ever to be remembered that erysipelas is a septic disease and is intimately connected with uncleanliness.

Diphtheria.

Diphtheria is a micro-parasitic disease, affecting primarily the mucous membrane of the fauces and larynx, but it may also develop on other mucous surfaces, or even in wounds. The micro-organism develops a poison at the seat of the infection, one of the most striking effects of which is paralysis—but the latter is not constant.

(327) *Mortality from Diphtheria.*

From 1855-80, a period of twenty-six years, there have been registered 89,603 deaths from diphtheria in England and Wales, which gives for those years an average death-toll of 3,446 annually. More females die than males; this excess is real, and not to be accounted for by the excess of female population. The deaths from diphtheria among the female population are 12 per cent. above the male population, whereas the number of females living exceeds that of males by 5 per cent., leaving an excess of 7 per cent. which cannot be attributed to the disparity of the sexes.

(328) *Geographical Distribution of Diphtheria in England and Wales.*

This has been carefully studied by Dr. Longstaff (17*th Annual Report Local Government Board. Supplement.*) He has taken his facts from the abundant statistics of the twenty-six years ending 1880, and has graphically displayed in a shaded map the local mortality; the depth of tint being proportional to the degree. The small fatality of diphtheria in Devonshire, Cornwall, and the Midland counties, contrasts in a striking manner with the blackness of Norfolk, the eastern counties, and the dark tint of Wales. He shows that diphtheria has always displayed a tendency

to prevail in sparsely-populated districts rather than in centres of population; as years have gone on, this tendency has become less and less marked, so that there has been a progressive tendency to equalize the special mortality in urban and rural districts. To sum up in nearly his own words the result of this inquiry:—Whatever units of area are taken in the examination of the geographical distribution of diphtheria in England and Wales, the same general results are arrived at. The distribution of diphtheria is apparently *sui generis*, the mortality from the disease clearly is not regulated by the same causes as influence the general mortality, certainly density of population does not favour it. This disease appears rather to have a preference for special districts, the great majority of which may be described as rural, and which have but a small proportion of their people living in towns; indeed several of these districts, notably Rothbury, Solihull, Hailsham, Petersfield, Ledbury, and Tenterden, have such a very low general death-rate (varying from 15·3 to 17·7 per 1,000), that they fairly claim to be amongst the healthiest areas in England. On the other hand, whilst among those districts which have to a great degree escaped the ravages of diphtheria there are some notably healthy areas, such as Farnham and Andover (with death-rates of 16·7 and 17·7), there are also a number of towns of medium or large size, some of which, such as Leigh, Bolton, and Wigan, have high general death-rates, ranging from 23·5 to 27·1.

The geographical distribution of the other diseases is totally different to that of diphtheria. That summer diarrhœa is especially a disease of towns is a familiar fact to which attention has repeatedly been called by the Registrar-General. Measles is especially fatal in London; scarlet fever is most common in the mining and manufacturing counties—Durham, Yorkshire, Northumberland, Staffordshire, Warwickshire, Cheshire, Lancashire, Monmouthshire, and South Wales.

Fifty-seven per cent. of the deaths of males and 51 per cent. of the deaths of females occur in the first five years of life; in the next five years 25 and 29 per cent. respectively, while after the forty-fifth year is reached only 2·5 per cent. of the deaths of males, and 2 per cent. of the deaths of females takes place (Longstaff). The average deaths per 1,000,000 during the twenty-six years mentioned were for males 157, for females 168.

(329) *Researches on the Bacteriology and Pathology of Diphtheria.*

A number of competent observers have, during the last ten or twelve years, devoted themselves to researches on the nature of diphtheria. The student will find an excellent study of these researches up to 1884 in Loeffler's classical paper published in the *Mittheilungen des Kaiserlichen Gesundheitsamte*, Berlin, 1884.

Especial value attaches to the researches of Oertel,[1] Loeffler,[2] and Klebs.[3]

Loeffler, Klebs and Oertel agree in finding on the diphtheritic surface a large number of micrococci and various non-pathogenic forms of micro-organisms; some of the micrococci seem to agree with the characters of the septic kinds and penetrate more or less into the mucous tissue. These, when isolated by cultivation, may produce in animals abscesses or a kind of pyæmia and death, but do not produce diphtheria. On the other hand, a micro-organism first carefully described by Klebs, may be considered the bacillus of diphtheria. These bacilli are 6·4 μ long and 1·1 μ broad, they have one or both ends swollen. They have no power of self-movement. They are intensely stained by methylene blue. Spores have not been definitely observed, and since it is found that when exposed for half-an-hour at 60° C. the life of the bacilli is destroyed, this behaviour to heat is not consistent with the presence of spores. To propagate the bacilli by artificial means in cultures, a temperature a little above 20° is necessary. Loeffler considers them capable of retaining their vitality for three months.

Inoculated in various ways into mice or rats, both species are found to possess immunity. On the other hand, small birds, guinea-pigs, fowls and pigeons may all be successfully inoculated; fowls are less sensitive than small birds.

Loeffler made one experiment on a long-tailed Java monkey, the result was negative. Possibly diphtheria may be communicated to the anthropoid apes, for there is a case on record of a chimpanzee dying from true diphtheria in the Hamburg Zoological Gardens.[4] The general effect of inoculating an artificial cultivation of the

[1] See M. J. Oertel. *Die Pathogenese der epidemischen Diphtherie.* Leipzig, 1887.
[2] *Op. cit.*
[3] Klebs. *Archiv f. experimentelle Pathologie u. Pharmakologie.* Bd. I, iv,
[4] Hilgender and Paulicki in *Centralblatt für die medicinischen Wissenschaften*, 1869, No. 47.

bacillus subcutaneously or into the mucous membrane of the trachea of a guinea-pig is somewhat as follows:—at the place of inoculation there is rapidly formed a fibrinous exudation, and death follows about the second or third day. The post-mortem characters are hæmorrhages and inflammatory points in the muscular structure, capillary extravasations and bleeding in the internal organs, swelling of the glands and of the spleen. The specific bacilli are confined to the affected mucous membrane or to the seat of inoculation.

Loeffler summarises the results of his experiments on guinea-pigs in the following words:—"The facts illustrate in a convincing way, that the death of the animal was not caused by a spread of the organism generally throughout the body, but through a different kind of action developing locally. The hæmorrhagic œdema, the fluid in the pleura, the lobular brown consolidation of the lungs, which, without the presence of bacilli, develop in these organs, definitely prove that a poison produced at the seat of infection circulated through the blood stream, which was capable of causing profound changes in the walls of the vessels." Very instructive were also the experiments of Loeffler on inoculations of the vaginæ of young guinea-pigs. The vaginæ of the guinea-pig is closed by a fold of skin; a disturbance of this fold causes a superficial, and to the naked eye, invisible erosion of the epithelium, yet this is a sufficient lesion for the penetration of the bacillus and the production of a fatal diphtheritic vaginitis. With old guinea-pigs the epithelial layer is thicker, and a great proportion of such experiments fail.

Reverting now to the observations of Loeffler on the pathological appearances in the human subject, a typical case may be quoted. In a boy five years old who died of true diphtheria on the seventh day of the disease, the post-mortem appearances were as follows:—pseudomembrane in the throat, larynx and trachea, hæmorrhagic broncho-pneumonia. No noticeable change in the other organs. Sections were made of the uvula, tonsils, lungs and spleen. The extreme tip of the uvula was destitute of epithelium, in place of which it was covered by a closely adherent broad pseudo-membrane. In the most superficial layer of this were numerous micrococci and rods, beneath this was a layer with many nuclei, then followed the typical bacilli; where these ceased, the

broad zone of colourless exudation, in which numerous blood corpuscles and a few nuclei appeared. This zone passed into tissue full of leucocytes, escaped blood corpuscles and nuclei in which ran full blood-vessels enormously dilated. In the follicles of the tonsils the epithelium was wanting, in its place was a fibrinous nuclear exudation but which contained no bacilli. In the trachea the exudation was in several layers, in the upper part of which there were bacilli of various kinds, whilst in the deeper parts as well as in the tissue no bacilli were found. In the sections of the lungs the capillaries were filled with blood corpuscles and colourless cells. In the interstitial tissue there were numerous leucocytes, in the alveola a fibrinous and cellular exudation but no bacteria. There were also no bacteria in the spleen.

Thirty cases of diphtheria investigated by Oertel gave somewhat similar results. The general conclusions which may be fairly drawn from the observations of Oertel and of Loeffler is that the disease known under the term diphtheria, consists of at least three forms. In the one the septic infection predominates, and whether Klebs's bacillus was originally present or not, the sufferer is affected with a disease closely analogous, if not identical, with septicæmia; in such a case there will be no membranous exudation, and the sequelæ of paralysis will not be observed. In a second class of cases there is a more or less copious exudation, and in this form Klebs's bacillus will be found, and paralysis may occur as a sequela, but it is not essential. A third form appears to be a mixture of septic and true diphtheritic infection.

(330) *The Nature of the Diphtheritic Poison.*

According to Roux and Yersin [1] the diphtheritic poison resembles the diastases in some of its properties. A filtered liquid capable of killing guinea-pigs in subcutaneous doses of one-eighth of a c.c., when heated to 38° for two hours, only produces œdema at the seat of inoculation when injected in doses of a c.c. The same liquid, boiled for twenty minutes, may be introduced into the veins of a rabbit in a dose of 35 c.c. without causing immediate illness, whilst, before boiling, one-half c.c. would have produced certain death. Animals which receive in the veins or under the skin

[1] *Annales de l'Institut Pasteur*, July, 1889; *Public Health*, vol. ii, p. 112.

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large quantities of liquids which have been thus heated, although at first presenting no symptoms, nearly always die after a longer or shorter time. They emaciate, although eating as usual, and show symptoms of paralysis, chiefly in the posterior limbs, a few days before death.

Roux and Yersin have sought to discover in the bodies of persons dead from diphtheria the same poison. The spleen of an infant dead from infectious diphtheria was macerated in sterilized water, and the liquid filtered through porcelain ; 35 c.c. were injected into the veins of a rabbit, and 8 c.c. subcutaneously into a guinea-pig. The latter died five days after the injection. The rabbit survived for two months ; at first well, it emaciated little by little, and died paralyzed in the hinder extremities.

In another case of diphtheria the urine was collected when the prostration was very marked, filtered fresh, and injected into the veins of a rabbit and under the skin of a guinea-pig. Eleven days after, the guinea-pig, much emaciated, was dead. The rabbit was paralyzed in the hind extremities on the 45th and died on the 51st day. If these animals be compared with those which have been treated with cultures boiled and filtered, the cause of death in both cases will be seen to be the same. Heat destroys a great part of the poison, or induces a modification similar to that which it undergoes in the organism.

Kept in close vessels, preserved from air and light, filtered cultures of diphtheria long preserve toxic properties. A filtered liquid was found after five months to be as poisonous as the day in which it was sealed up in tubes. Exposed to the air its toxic properties gradually diminish. This action of the air is slow in the dark, rapid in the solar light. After two hours of insolation 1 c.c. of a liquid exposed to the air killed guinea-pigs; the same dose after five hours caused only local œdema. But when not exposed to the air, ten hours of sunshine had but little effect.

Cultures of the diphtheritic bacillus have only energetic toxic properties when they become alkaline ; when acid, large doses of the filtered liquid are required to affect animals.

Evaporated in a vacuum at 25°, a residue is left which, when dissolved in a little water, is very toxic, because it contains in small volume the active matter of a large quantity of the culture. An alcoholic extract is innocuous, therefore alcohol does not dissolve

the poison. The active matter may be precipitated by absolute alcohol in the form of white greyish flocculi, exactly in the same way as an aqueous solution of diastase is precipitated by alcohol.

When a diphtheritic culture is submitted to dialysis, the outer liquid is found to be lethal. Like the diastases, it also has the property of adhering to certain precipitates.

The best precipitate is phosphate of lime. By fractional precipitation with calcic chloride, and essaying after each precipitation the effect of the liquid, it was found that in general the second precipitate was the most active. The dried precipitate is not so active as the moist, but it retains its properties a long time. Even after being heated for twenty minutes in the water-bath at 100°, it will kill guinea-pigs. This is, therefore, a convenient method of preservation of the diphtheritic poison.

An attempt was made by Roux and Yersin to ascertain the quantity of the dry organic matter which must contain the toxic material requisite to cause death in guinea-pigs or rabbits. A c.c. of active liquid gives a centigramme of dry residue; on subtraction of the ash and the portion soluble in alcohol which have no toxic action, there remain two-fifths of a mgrm. of organic matter; but it is certain the greater part of these two-fifths are formed of other substances than the diphtheritic poison. This weak dose is yet sufficient to kill at least eight guinea-pigs weighing 410 grammes, or two rabbits of 3 kilos each; a dog weighing 9 kilos, should he receive these two-fifths of a mgrm. in his blood, if he does not die, will remain very ill for a long time.

Hence it follows that if the real poison could be separated in a state of absolute purity, it would be lethal to guinea-pigs in a less dose than 0·75 mgrm. per kilo ($\frac{1}{200}$ gr. per lb.), to rabbits in a less dose than 0·13 mgrm. per kilo.

(331) *Klein's*[1] *later Researches on Diphtheria.*

While these sheets were passing through the press Klein has published researches, which, if confirmed, throw considerable light on the etiology, and in some points modify the foregoing account. In the first place he found that cultures of Klebs's bacillus were

[1] Report of Medical Officer in *Supplement to Eighteenth Annual Report of Local Government Board*, 1888—1890. *Proceedings of the Royal Society*, 1890.

virulent to guinea-pigs on subcutaneous injection, but that the disease thus produced could not be considered diphtheritic. The same cultures were inactive when tested on fowls, pigeons, and rabbits. He next experimented with human diphtheritic membrane and found that pigeons, fowls, and rabbits were resistant to its action, but that guinea-pigs when inoculated with the membrane died of a septic infection, and he could not consider that the reaction was of a diphtheritic nature.

The true bacillus of diphtheria according to Klein is not that discovered by Klebs, but one which is shorter, and its most striking difference to that of Klebs is that it grows on gelatin at 20° C., whereas the bacillus of Klebs does not grow at all below 22° and flourishes best at 35°-37°. The bacillus of Klein seems to be readily obtained in a state of purity by inoculation of a cat's cornea with human diphtheritic membrane, as in the experiments to be mentioned.

Experiments upon cats with human diphtheritic membrane gave some striking results. On various occasions during the last few years there have been observations of some relation between human diphtheria and a malady in cats; instances such as *e.g.*, that a cat or cats were taken ill with a pulmonary disease, and when ill were nursed by children, and then these latter sickened with well marked diphtheria. Or reversely, children were taken ill with diphtheria and either at the same time or afterwards the cat or cats sickened. The disease in the cat was described as an acute lung trouble; the animals were quiet, did not feed and seemed unable to swallow. In some cases they recovered; in others they became emaciated, while the lung trouble increased, and they ultimately died. In one instance the cat malady occurring where children were soon after attacked by diphtheria was of a wide-spread nature; and *post-mortem* examination of the animals affected showed severe lung disease, broncho-pneumonia, and large white kidneys due to fatty degeneration of the entire cortex; a similar condition being also met with in the human subject as an effect of diphtheria.

Subcutaneous inoculations into cats were carried out with particles of fresh human diphtheritic membrane and with cultures of the diphtheritic bacillus, producing a local diphtheritic swelling at the seat of inoculation and general visceral disease. In the cases

in which death followed after a few days the lungs were found much congested, and when death followed after one or more weeks the lungs showed broncho-pneumonia, and the kidneys were enlarged and white, the cortex being in a state of fatty degeneration. If the disease lasted beyond from five or seven days, both kidneys were found uniformly white in the cortex; if of shorter duration, the fatty degeneration was sometimes only in patches, although in these experiments the bacillus was recoverable by cultivation from the swelling at the seat of inoculation. No bacilli were found in the lungs, the blood, or the kidneys, and hence the conclusion is justified that, as in human diphtheria and in that produced by the inoculation of guinea-pigs, so in these experimental facts the visceral disease was the result of the action of a chemical poison produced by the growth of the bacillus at the seat of inoculation. From this it is seen the similarity between the natural and the artificial disease in the cat is very great, and the question arises as to the manner in which the cat either receives or imparts the diphtheritic contagion in the natural disease. This natural disease is in its symptoms and pathology a lung disease, and it is reasonable to suppose from analogy that the lung is the organ in which the diphtheritic process in the cat has its seat. The microscopic examination of the diseased lungs of a cat dying from the natural disease bears out this supposition, the correctness of which has also been proved by direct experiment. Broth culture of the special bacillus was introduced into the windpipe of cats without injury to the mucous membrane. The animals became ill with acute pneumonia, and on *post-mortem* examination from two to seven days later there was found extensive pneumonia and fatty degeneration of the kidneys. The air passages contained an exudation like that of human diphtheria and the bacilli were present in large numbers. During the last ten or twelve years several epidemics of diphtheria have been traced to milk, but the way in which the milk became contaminated with the diphtheritic virus was not ascertained, although the evidence was very strong that it had not been from a case of disease in the human subject. The cows which yielded the milk were not reported to be unhealthy, except for having sores or chaps on their teats. Klein inoculated a broth culture of the diphtheritic bacillus into two cows. On the second or third day there was a soft tender swelling at the

place of inoculation which reached its maximum at the end of a week and then gradually became smaller and firmer. The animals had a raised temperature and left off feeding on the second or third day, then to all appearances recovered; but on the eighth or tenth day, they were attacked by a slight cough which gradually increased; both became emaciated; one died on the fifteenth day, the other was killed (being very ill) on the twenty-fifth day. During the illness both animals had an eruption on the teats and skin of the udder. From one of the cows on the fifth day milk was drawn from the healthy teat, the outside of the teat and the milker's hand having been first thoroughly disinfected from this milk cultivations were made, and it was found that thirty-two colonies of diphtheria bacillus without any contamination were obtained from a single cubic centimetre. Contrary therefore to what happens in the guinea-pig and in the cat; the diphtheria bacillus passes from the seat of inoculation into the system of the cow and makes its appearance in the milk. The presence of the bacillus in the eruption on the udder was also demonstrated both by microscopic examination and experiment. Two calves were inoculated with matter from this eruption and both developed a similar eruption, besides becoming affected with severe broncho-pneumonia and fatty degeneration of the kidney. It therefore appears that a definite disease can be produced in the cow by the diphtheria bacillus and the contamination of the milk shows that the bacillus contaminates the general system.

At the beginning of the month of April, two cats died at the Brown Institute after having been ill for several days with symptoms like those of natural cat diphtheria between the beginning of April and the beginning of May; fourteen cats became similarly affected, some more severely than others, and some died with the characteristic morbid changes. This epidemic, as it may be called, commenced with the illness of the first two cats about the end of March; and the question arises as to how the disease originated in these two animals; no cats had been ill in their shed and the two affected ones were healthy when received at their institution some weeks later. But during the latter half of March there were in the stables of the institution two milch cows ill with diphtheria induced by inoculation with the human diphtheria bacillus—in fact the two cows already referred to. The diphtheria bacillus

was found in the milk of one of these animals on the fifth day after inoculation, and orders were given to the attendant that the milk of both cows was to be thrown away. This order was not obeyed, for part of the milk was given to the two cats above mentioned, and they sickened as described within a day or two afterwards. It ought to be mentioned that the man in attendance on the cows had also charge of the cats, but in view of the fact that he himself was free from the disease the possibility of his having conveyed it to the cats may be dismissed.

(332) *The Prevention of Diphtheria.*

A common source of infection is actual contact with persons suffering from diphtheria. It is not unfrequently produced from the unnecessary and very dangerous plan of sucking a tracheotomy tube in order to clear it.[1] There are epidemics on record distinctly connected with milk. Nevertheless a large proportion of the cases are obscure in origin. It is noteworthy that in Loeffler's investigation into the organisms of the healthy mouth and throat he found in one case Klebs's bacillus, so that it may be presumed it gets access to persons' throats without necessarily causing illness. Persons with large tonsils and relaxed throats are probably more liable to be attacked than those whose mucous membranes are in a healthy state, for the micro-organism has then opportunities to attach itself to the interior of a follicle, and unless destroyed by other saprophytic bacteria, or by the secretions of the mucous membrane, to divide and multiply, and get access ultimately to the deeper layers of the tissue. One important factor in prevention of diphtheria is, therefore, when diphtheria is epidemic for persons with weak throats to apply local applications under advice so as to get the mucous membrane into a healthy and therefore resistant condition.

If the view is correct that a large proportion of the cases are septic, such are likely to be caused by bad drainage, and foulness

[1] It is obvious that a wash-bottle arrangement containing at the bottom of the flask a solution of corrosive sublimate or else strong carbolic acid, and from the glass tube which dips beneath the liquid a rubber tube carrying a little nozzle fitting in the silver canula, would make a most effective apparatus to clear the tracheotomy tube, and the operator could not be directly infected, for the sucked out matter would pass into the disinfectant. By drawing air through the shorter tube a very considerable vacuum will be produced.

of all kinds. The possibility of infection from cats in the light of Klein's recent research must also be remembered. Diphtheria actually present in a house, the patient should be isolated, and those in attendance should spray the throat with a half or one per cent. solution of carbolic acid two or three times a day. The writer has known families which have taken this precaution and escaped, although for days in hourly contact with bad cases of diphtheria. So far as is known, the diphtheritic poison is easily destroyed, and therefore the disinfecting measures described at page 358 should be successful.

PUERPERAL FEVER—SEPTICÆMIA—PYÆMIA—BLOOD-POISONING.

(333) *Influence of Season on Septic Diseases.*

The above names are given to diseases which have so much in common that, in a public health sense, they may be considered almost identical save in relation to sex, and as to whether they arise from external wound or otherwise.

Puerperal fever and septic diseases generally are also closely allied to erysipelas, for when erysipelas is frequent, puerperal fever and the other septic class are also frequent in their incidence; whereas when erysipelas is not frequent, there are also fewer cases of the septic class than usual. For example, take the twenty-five years ending 1888: the maximum number of puerperal fever deaths occurred in 1874 (3,108), in the same year the maximum number of deaths from erysipelas (3,358) were registered; in 1867 occurred the minimum number of puerperal deaths (1,066), in the same year the minimum number of deaths from erysipelas (1,446). The two curves also given by Buchan and Mitchell, showing graphically the seasonal mortality variations for each week of the year, based upon the mortality records for thirty years ending 1874, show the same general fluctuations for erysipelas and for puerperal fever. The minimum of each falls in the latter end of August, the mortality rising gradually, to attain the maximum in the last week of November, to decline somewhat throughout December, but to be still above the average, to rise again in January, and then to gradually decline through the succeeding months to the lowest point in August.

(334) *Statistics of Puerperal Mortality.*

The actual number of deaths from puerperal fever in the twenty-five years ending in 1888 was 46,162, the number of births (living) was 19,746,768, which would give a rate per birth of 2·3 per 1000. The rate is not quite so high as this, because the number of births (living) is less than the number of confinements. The mean yearly number of puerperal deaths is 1,846; the maximum, as before stated, fell in 1874 (3,018), the minimum in 1867 (1,066). These maxima and minima do not coincide with the maximum or minimum of birth: the greatest number of births took place in 1884 (906,750), the least number in 1864 (740,275).

During the three years ending 1888 (the full returns have been published for the last three) there has been an increase of death from puerperal fever in relation to the number of births, the rate per thousand births being for those three years 2·6 per thousand. This increase occurs in confinements treated at the woman's own home by medical practitioners, midwives, &c., and not in the lying-in hospitals.

The use of disinfectants has caused a complete and happy change in the mortality of lying-in institutions. In the largest childbed institution of the world, viz. the Vienna Lying-in Hospital the mortality previous to 1862 was 28 per 1,000; then by hygienic reforms it was reduced by 1880 to 16 per 1,000; lastly, during the period since 1880 it has fallen to 7 per 1,000. At Dresden the mortality has been reduced from 50 per 1,000 to 10 per 1,000. The mortality at the Maternité in Paris has been reduced by the same agencies from nearly 10 per cent. to 11 per 1,000. In our own institutions, such as Queen Charlotte's Hospital, and the General Lying-in Hospital, York Road, puerperal fever is almost unknown. It is therefore evident that midwives and a large proportion of the profession can either not use antiseptics, or are not able to enforce their use in the subsequent nursing. As Dr. Cullingworth [1] has already stated, in pleading for the more general use of antiseptics in obstetric practice:—"The lying-in hospitals have very properly led the way, and it now rests with those engaged in private practice to take the matter up. It was obvious that the 2,078 deaths certified as having occurred in England and

[1] *Public Health*, vol. i., p. 210.

Wales from puerperal fever in 1886 could not have all taken place in hospitals. Indeed, two-thirds of them occurred in counties where not a single lying-in hospital existed. It was not, therefore, a disease of hospitals alone. The only way to avoid this terrible mortality, and to avoid also the enormous amount of puerperal disease which, because it was not fatal, remained unrecorded, was for every practitioner to recognize his responsibility in the matter. The use of antiseptic precautions in midwifery practice in Germany was made compulsory by the State. The tendency of public opinion in this country was not in the direction of compulsory legislation in such matters. The use of antiseptics in Great Britain was, and was likely to remain, a question of individual responsibility, not of penal enactment. Surely it ought not on that account to be considered the less binding."

(335) *Bacteriology of the Septic Diseases.*

In the septic diseases generally, there have been various micro-organisms, such as bacilli and cocci, found, which, when isolated by cultivation, and the cultures injected subcutaneously, cause abscess, or purulent foci, or gangrene, or erysipelatous inflammations in the lower animals. It is pretty certain that in puerperal fever and septicæmia one or more pathogenic micro-organisms cause the illness. In the puerperal state, the raw surface of the uterine mucous membrane, and any laceration of the peritoneum or other parts, afford an excellent soil for pathogenic microbes ; in other cases a wound or abrasion of the skin is the portal through which the mischief enters; in others again there is a direct infection or inoculation, such, for example, as the pyæmia which so often ensues after wounds occurring in dissection. There is another class of cases, which seem to depend upon bad drainage or foul emanations ; this class of blood-poisoning, which often runs its course similar to traumatic pyæmia, is obscure, and requires farther investigation.

(336) *The Duty of the Health Officer in relation to Puerperal Fever.*

Under the Notification Act, cases of puerperal fever must be certified by the medical man, notified by the householder. It

should certainly be the duty of the health officer to make inquiry into each case; he should specially direct his investigation as to the previous confinements which either doctor or nurse has attended, and as to whether the medical attendants used disinfectants in washing their hands, or as to whether antiseptic vaginal injections had been used. The drainage and sanitary condition of the house should also be strictly investigated.

Since these maladies are not easily communicated unless by direct inoculation, or unless persons in the vicinity of the sick have abrasions of the skin, cuts, or wounds, it is not absolutely necessary to remove the patient to hospital on public grounds; but if the lodging is itself insanitary or overcrowded, it may then be advisable to urge such removal.

(337) *Disinfectants in the Puerperal Condition.*

A 1 per 1,000 solution of corrosive sublimate for general use—that is, both for washing the hands and as a vaginal injection—or a 5 per cent. solution of carbolic acid, will be found the best. (Reference may be also made to the trichloride of iodine, see page 345.) After an obstetric physician has attended a case of puerperal fever, it has been found most difficult to get free from infection. The main trouble probably is to disinfect the recess between the nail and the finger. From experiment it has, however, been shown that, if the hands are washed with as hot water as can be borne, then with strong alcohol, and then with a strong disinfectant, such as a solution of iodine trichloride, the hands may be made to yield sterile scrapings even when such scrapings are derived from under the nail. This, with two or three Turkish baths, followed by sponging the whole body over with a 1 per 1,000 solution of corrosive sublimate and absolutely fresh clothing, the clothing taken off being sent to the disinfecting chamber, will, if carried out honestly and intelligently, most certainly free the physician's body from any infective particles.

CHAPTER XXX.

TUBERCULAR MALADIES.

Tuberculosis.

Tuberculosis is an infectious malady, caused by a micro-organism to which has been given the name of the *Bacillus tuberculosis*. The bacillus once planted in the tissues may give rise to a mere local lesion, as for instance when it is inoculated into the skin; or may affect one particular organ, such as the lung, far more than any other part; or may be generally diffused.

(338) *Statistics of Tubercular Mortality.*

Hitherto we have had no trustworthy guide as to the number of cases of tuberculosis, save that of the death returns. In the Registrar-General's returns tuberculosis is divided into phthisis, tabes mesenterica, tubercular meningitis, and "other forms of tubercular disease and scrofula." Some of the latter are probably not correctly diagnosed, but on the other hand it may be safely affirmed that a number of cases escape diagnosis, and that the mortality is rather likely to be under- than over-stated.

During the twenty-five years ending 1886, the average total deaths from phthisis have been 50,000 yearly in England, and those from other tubercular affections 17,700—in all, nearly 68,000.

An interesting summary is given by the Registrar-General of the deaths from tubercular diseases of children under five years of age for the three decades from 1871 to 1880:—"The death-rate from phthisis in the years 1851-60 was 1,305 per million: from

tabes mesenterica and scrofula, 1,920. In 1861-70 the figures are 968 for phthisis, 2,213 for hydrocephalus and tubercular meningitis, and 2,267 for tabes mesenterica and scrofula; whilst in 1871-80 the figures are 767, 1,800, and 2,550."

In relation to these Dr. Sims Woodhead[1] remarks:—"The differences in the proportions between these figures in the various years might be due in part to more accurate diagnosis, but in part they are to be accounted for by the increase in the death-rate from tabes. Including, as these cases do, the diagnoses of physicians both skilled and unskilled, it would appear from the results of *post-mortem* examination of the cases described that the last group might safely be multiplied by five to give the actual number of cases in which the mesenteric glands were affected, giving no less than 12·75 per 1,000 as the rate of disease. If, in addition, those cases are taken in which the tubercular is followed by a reparative process, the number must be enormously greater."

(339) *The Influence of Age and Sex.*

Females are more liable to tubercle than men, in the proportion of about 0·2 per 1,000 of the population. It may be stated generally that the mortality is greatest at birth, diminishes rapidly till the fifth year, more gradually till about the fifteenth, and then begins to rise, at first slowly, then rapidly to the end. In the early years taken as a whole, the mortality is low, but from fifteen to twenty-five it is high; after this age the mortality somewhat declines. It must however be remembered that during the first five years of life errors in diagnosis are most common, and it is probable that many children die from tubercular meningitis and from tabes, the deaths being returned as from convulsions, teething, diarrhœa, and so forth.

Different organs are affected at very different periods of life. Thus Dr. Woodhead remarks that tubercular meningitis occurs much more frequently between the third and the eighth years than it does at any other period of life. Rilliet and Barthez give the results of the examination of 98 cases of this condition. They state that during the first year there were only two cases; be-

[1] "Abstract of the Researches of Dr. G. Sims Woodhead," *Public Health*, vol. i., 1888.

tween one and two years and a half, 17; from three to five years and a half, 34; from six to seven years and a half, 23; from eight to ten years, 15; and from eleven to fifteen years, 7 cases.

Of 54 cases of tubercular meningitis examined by Dr. Woodhead, not one was under one year (adopting the same classification); between one and two years and a half there were 15; from three to five years and a half, 21; from six to seven years and a half, 8; from eight to ten years, 8; and from eleven to fifteen years, 2. These figures correspond fairly closely, and might serve as a basis for comparison. In these 54 cases, tuberculosis was in 39 so widely disseminated that it might fairly be said to be general; in only 2 cases could no primary centre of infection be found. In 6 the only foci that could be primary were to be found in the lymphatic glands of the mediastinum alone or along with those of the mesentery; in 3 the lungs were the only other organs affected; and in 1 the lungs and mediastinal glands contained the older tubercle nodules.

In the brain or in its membranes, the embolic tuberculosis must be looked upon as part of a general process. Intestinal tubercle is most common in the years following childhood from twelve upwards for six or seven years. From an analysis of 127 cases of tuberculosis in children it was found that in 43 instances there was tubercular ulceration of the intestine. During the first year after birth there was only 1; between one and two years and a half, 14; from three to five years and a half, 10; from six to seven years and a half, 7; from eight to ten years, 5; and from eleven to fifteen years there were 6. So that in this series of cases the intestines are frequently affected during very early life as well as in somewhat later years. Although the intestines are directly affected by tubercle in such a small proportion of cases, the mesenteric glands are found to be in some stage or other of tubercular degeneration in no less than 100 instances, or in nearly 79 per cent. of the whole. The age at which these tubercular glands in the mesentery were found is also significant. During the first year of life there were 4 cases; from one to two years and a half, 33; from three to five years and a half, 29; from six to seven years and a half, 12; from eight to ten years, 13; and from eleven to fifteen years, 9 cases. Here again the figures are higher during the earlier periods than during later years, but the maximum is

reached (as with ulceration of the intestine) at a distinctly earlier period than in the case of tubercular meningitis. In 14 cases the glands only were affected—*i.e.*, there was no tubercle found in any other part of the body. In these cases the glands had become calcified, but in the others the structure and degeneration of the glands were tubercular, bacilli were very few in number and in some cases could not be demonstrated, and the nature of the mass could only be determined by inoculation experiments. Here, again, the second and third periods account for more than all the others put together, 5 and 4 from one to two and a half years and from three to five and a half years, against 5 for the other four periods (1 under one year; 1 between six and seven and a half years; 2 from eight to ten years; and 1 from eleven to fifteen years). These 14 cases were accompanied by neither ulceration nor cicatrisation of the intestine; there was no peritonitis, and secondary tubercle could be found in no other parts of the body, so that the tuberculosis of the mesenteric glands must be looked upon as the primary lesion. Continuing the analysis, it was found that in this 100 cases the glands at the root of the lung were simultaneously affected in 69 cases; and in 62 the lungs were also affected; in 13 there was tubercular peritonitis, and in 18 ulceration of the intestine was also found. Of the remaining cases, 4 had tubercular peritonitis and 4 ulceration of the intestine. In 12 cases the mesenteric and mediastinal glands, the peritoneum, the intestine, and the lungs were all affected; whilst in no fewer than 53 of the 100 cases there was evidence of localised peritonitis, recent or old, occurring between the spleen or liver and the diaphragm. Of the whole 100 cases, only 20 were diagnosed as having abdominal tubercle, and this 20 would be considerably reduced were the doubtful diagnoses eliminated. In these cases, then, the symptoms associated with tubercle in other organs are so predominant that the tubercle in the abdomen was practically overlooked. Dr. Goodhart, speaking of this condition, says: "Caseous or tubercular disease of the mesenteric glands is not uncommon; nevertheless, it is rare indeed in comparison with the consumption of the bowels which is so often heard of in the dwellings of the poor. From a large out-patient department of the Evelina Hospital during several years, and when at least 6,000 or 7,000 children must have come under observation, and probably considerably more, I have

only note of 46 cases, and half of these were but of doubtful nature. Some few others are to be associated with phthisis, but as a substantive ailment we might have supposed it to be more common than it is." And Professor Gairdner, in his *Lectures to Practitioners*, draws attention to the fact that as pathological descriptions can deal with fatal cases only, a far too grave prognosis is arrived at in case of tabes, and that consequently many cases of tubercular disease, not only of the mesenteric glands, but also of the peritoneum, recover, only the more grave cases succumbing. It is evident from all this that tubercular conditions of the abdomen are much more common than can be inferred even from the figures above quoted, where only one-fifth of the real number are stated in the diagnosis charts to be suffering from abdominal tubercle. That there is a great tendency towards calcification and cicatrisation, especially where the tissues have a high resistant power, is well known to all pathologists, who constantly find cicatrices which are to be recognised as of tubercular origin (by the presence of small caseous or calcareous nodules, etc.), in which, however, the tubercle has become quiescent. These are the result of local tubercular changes, the localisation being due to the activity of the tissues.

(340) *Probability of a Person Dying from Consumption.*

The late Dr. Farr from his life table calculated that 114,417 out of 1,000,000 children born would die of phthisis; at some or other period of their lives these might therefore be considered predisposed, or in other words they had less resistant power than other people. He then constructed a hypothetical life table of the class dying or to die of consumption, by picking out the survivors of the 114,417 at any age and putting them into a class apart. Such a table illustrates well the effect of age, *e.g.*:—

NUMBERS TO DIE OF CONSUMPTION AT AND AFTER EACH AGE OUT OF 1,000,000 CHILDREN BORN.

Age x.	To die.	Age x.	To die.
0	114,417	35	54,290
5	109,948	45	31,886
10	107,809	55	15,418
15	104,283	65	4,973
30	95,209	75	679
25	81,424	85	52

(341) *Influence of Occupation on Tubercle Infection.*

Out-door occupations are less liable to tubercular maladies than in-door; a rural population is therefore less liable than an urban population. Those who are well housed and have ample cubic space are less liable than those living in the reverse conditions. The spread of tuberculosis in this respect strictly follows the law governing the spread of zymotic diseases generally. The one-roomed population of towns have a much higher mortality than those who can afford more than one room. Two causes tend to produce this result—the one is the low state of health breathing an impure atmosphere produces, and hence a less resisting power; the other is that the nearer the infected and the healthy are, the more prone is infection to be conveyed.

Dusty trades or occupations are especially liable to produce tubercular lung disease. C. Lombard (*Recherches Anatomiques sur l'Emphysème pulmonaire*) found the order of fatality to be (1) mineral dust; (2) animal; (3) vegetable. In 1,000 deaths from consumption of adults he found they could be classed according to their occupations as follows:—

Occupations with mineral and vegetable emanations	176
Occupations with various dusts	145
Sedentary life	140
Workshop	138
Hot and dry air	127
Stooping posture	122
Sudden movements of the arms	116
Muscular exercise and active life	89
Exercise of the voice	75
Living in open air	73
Animal emanations	60
Occupations in which watery vapour was breathed	53

This result is conformable to the micro-parasitic theory of tuberculosis. The researches of Greenleaf Tucker[1] and others have clearly proved that the number of bacteria in the atmosphere of a room or place is dependent upon the greater or less amount of dust. In a quiet room, such for example as a hospital ward early in the morning, before any dusting, sweeping, or bed-making has been done, the bacteria are very small in numbers because they have settled down with the dust on the floor, the walls, and

[1] *Massachusetts State Board of Health Report*, 1888.

other objects; the bacteria attain their maximum number when there is the maximum amount of dust in the air. It is therefore no wonder that a disease like tuberculosis, so widespread and against which no precautions are taken, infects the dust of work-shops and living rooms, and the bacilli, dust-borne, are breathed; nor is it a matter of surprise that metallic dust—that is, dust having sharp angles and spiculæ—should be more likely to wound the mucous epithelium and open a door as it were for the bacilli to enter, while the softer vegetable fibre has not so great an effect.

(342) *Influence of Soil.*

Drs. Bowditch and Buchanan, working independently, successfully established the fact that there is a relation between dampness of soil and tubercular affections. It is therefore probable that dampness of a house is also a predisposing cause, although the area in which the particular house stands may be dry. Sir John Simon and others have shown that the draining of soils diminish the death-rate from consumption. Dr. Andrews, of the Chicago Medical College, has studied the geographical distribution of consumption in the States, and has shown that there it is most abundant near the sea and diminishes as we recede from it. At equal distances from the sea it prevails at the north and diminishes towards the south. For example, beginning at Massachusetts and going westward, the proportion of deaths from consumption to deaths from all causes regularly diminishes as we recede from the Atlantic. Thus deaths from Massachusetts, 25 per cent.; New York, 20 per cent.; Ohio, 16 per cent.; Indiana, 14 per cent.; Illinois, 11 per cent.; Missouri, 9 per cent.; Kansas, 8 per cent.; Colorado, 8 per cent.; Utah, 6 per cent.; and then in California it increases again to 14 per cent. on account, according to Andrews, of the proximity of the Pacific Ocean. A similar decrease is observed in going from north to south—viz., Michigan, 16 per cent.; Indiana, 14 per cent.; Tennessee, 12 per cent.; Alabama, 6 per cent.

Hence tubercular disease seems to follow closely the moisture and temperature of localities. Massachusetts is ten times as fatal to consumptives as Georgia, and Minnesota is twice as fatal as Georgia. The combinations of damp soil, an atmosphere laden

with moisture, and variable weather, are the most favourable, and the reverse of these the least favourable, for the dissemination of the malady.

(343) *Influence of Season on Tubercular Fatality.*

This has been worked out in Buchan and Mitchell's research.[1] It would of course be more interesting to know at what season of the year the tubercular process commenced than when it terminated, but this is not possible until tuberculosis in all its forms is "notified" under the Infectious Diseases Notification Act.

Buchan and Mitchell have shown that the mortality from tabes follows very closely the temperature, the maximum being from the middle of July to the middle of September similar to the maximum of diarrhœa mortality, and in point of fact the deaths from tabes are mostly hastened by diarrhœa; the absolute minimum is from the end of December to the beginning of February.

The relation of phthisis to weather they have also delineated in a curve, and remark: "The absolute minimum occurs in the last week of September, after which it begins steadily to rise; in the middle of November it rises still more quickly; during the last three weeks of December it falls a little; rises again in the beginning of the year, and remains steady until the second week of March, when it rises to the annual maximum during March, April, and May. From the middle of July to the middle of November it is below the average. This is one of the most constant curves in its main features from year to year."

(344) *Bacteriology and Pathology of Tuberculosis.*

Those works are alone noticed which relate to the parasitic nature of the tuberculous virus. Other works on the etiology of tuberculosis are summarized in great part by Waldenburgh (*Die Tuberculose. die Lungenshwindsucht u. Skrophulose.* Berlin, 1869) and by Johne (*Deutsche Zeit. f. Thiermedicin.* IX Bd.).

It is known that Villemin, from his experiments on animals, expressed the view that tuberculosis could only be produced by a specific virus. This opinion was at first much contested, but shortly gained ground. Individual authors then maintained not

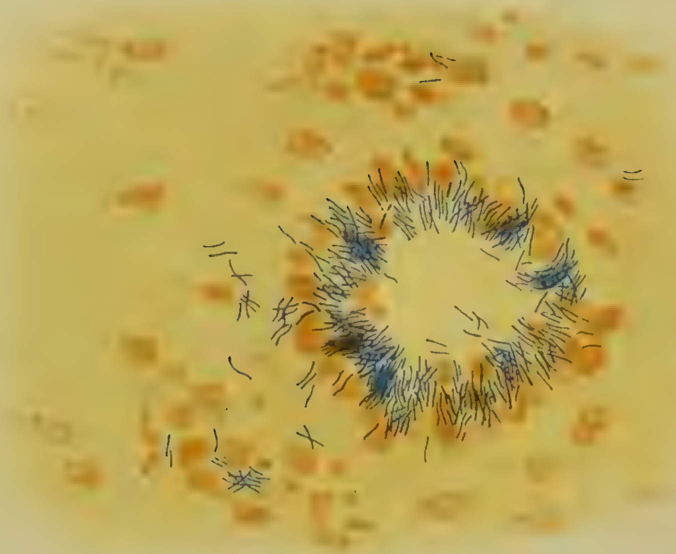
[1] *Journal of the Scottish Meteorological Society*, July 1874, 1875.

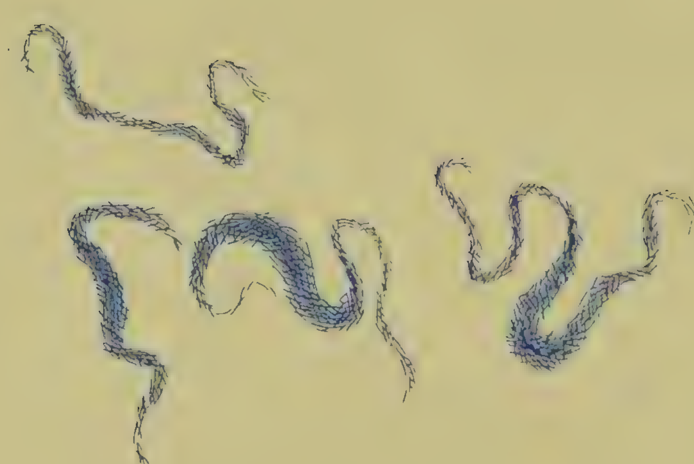
only the specific nature of tuberculosis, but that it was also probable the tubercular virus was parasitic, *e.g.*, Chauveau,[1] Baumgarten,[2] Ziegler,[3] and others. There was no want also of researches recognizing the supposed parasite. Thus Zurn,[4] had already found in the year 1872 in the tubercle of the cow, and in the inoculated tubercle of the rabbit, small punctiform molecules which he described as micro-cocci. Buhl[5] likewise maintained that in the cheesy masses and giant cells of tubercle, spherical and rod-shaped bacteria were present. Klebs[6] resorted to cultures, and by means of "fractional cultivation" obtained cocci-like organisms, through the inoculation of which he produced tubercles in animals, which tubercles contained similar organisms. Schiller[7] and Reinstadler[8] obtained the same results. Toussaint[9] also obtained from his cultures small cocci, mostly in pairs, the virulence of which increased with the number of successive generations. Aufrecht[10] found in tuberculosis short bacilli, the length of which were half as much again as the breadth; there were also two different kinds of micrococci. Deutschmann[11] lastly maintained that the cocci present in tuberculous pus, which indeed showed throughout the characters of the "monas tuberculosum" (Klebs), were not all of equal activity, only those contained in the deeper, more tenacious layers of the pus, containing cocci which could produce tubercle.

The researches quoted above, made by very imperfect methods, could not be confirmed, and still the nature of the tubercular virus remained unknown until at last Koch succeeded by his perfected method in discovering the parasite of tuberculosis, and established its etiological significance in a convincing manner.

In the first communication of Koch[12] on this subject a method of colouring the bacilli in sputum on microscopic glass covers, and in sections of hardened organs is described:—the preparation was

[1] *Rec. de Med. vet.* 1872. [2] *Berliner klin. Wochenscrift.* 1880.
[3] *Lehrbuch der allg. u. spec. Patholog. Anatomie.* 1881.
[4] *Zoopathologische u. Zoophysiologische Untersuchungen.* 1872.
[5] *Lungenentzündung, Tuberculose u. Schwindsucht.* 2 *Aufl.* 1873.
[6] *Tageblatt d. Versammlung Deutsch Naturforscher u. Aertze in München.* 1877; *Prager Medic. Wochenschrift.* Nos. 42 and 43. 1877.
[7] *Archiv f. exper. Pathol.* II. Band; *Experimentelle u. histologische Untersuchungen über Entstehung u. Ursache der Skroph. u. tuber. Gelenksleiden.* Stuttgart, 1880. [8] *Archiv. f. exper. Pathol.* II. Bd.
[9] *Comples Rend.* 1880. [10] *Pathologische Mittheilungen.* Magdeburg, 1881.
[11] *Centralblatt f. d. Medic. Wissenschaft.* No. 18, 1881.
[12] *Berliner klin. Wochenschrift.* No. 16, 1882.





first placed in a solution which contained in 200 c.c. of water 1 c.c. of a concentrated solution of methylene blue; to this was added 2 c.c. of a 10 p.c. solution of potash. The preparation remained in the solution 20—24 hours (or with warming to 40° only half an hour), afterwards it was placed in a concentrated solution of vesuvin for 15—20 minutes in the case of sections, and for but 1—2 minutes in the case of dried sputum. In this way the tubercle bacilli were coloured blue, the rest brown.

Two years later Koch[1] published a more complete and detailed account of his researches on the etiology of phthisis. Koch recommended in this treatise a modification of Ehrlich's staining method, which consists in placing the preparation in a solution composed of 100 c.c. aniline water, 11 c.c. alcoholic solution of methyl violet or fuschin, and 10 c.c. absolute alcohol. The preparation remains in this solution at least twelve hours, but the time can be shortened by warming; it is then transferred to dilute nitric acid (1:3), then washed for a few minutes with absolute alcohol (covering glass preparations only a few seconds) and finally coloured by soaking for a few minutes in aqueous solution of vesuvin or methylene-blue.

(345) *Characteristics of the Tubercle Bacilli.*

Koch[2] described the general characteristics of the micro-organisms as follows:—"They always appear in the form of rods the length of which is equal to that of half a red blood corpuscle (about ·0015mm. ·0035mm.). Though the length of the bacilli may vary somewhat, the diameter is constant so long as the same staining method is employed; the alkaline methylene blue process causes them to appear more slender than when stained with the process of Ehrlich. The bacilli are commonly not quite straight rods but there are found among them slight curves and often also slight twistings, in the longest examples, these may even suggest the notion of the commencement of a spiral. The bacilli are separated from other bacilli which come nearest to them in size and appearance by this tendency to curve."

See Plates II. and III. Plate II. *a* represents a giant cell containing numerous bacilli arranged in a radiating form × 700

[1] *Mittheilungen d. Kaiser. Gesundheitsamte.* 2 Band.
[2] *Mittheilungen aus dem Kaiserlich Gesundheitsamte.* Berlin, 1884.

(after Koch); *b* represents a few colonies derived from the artificial culture represented in Plate III. *b* × 700. Plate III. *a* is the naked eye appearance of an artificial culture of the tubercle bacilli on coagulated blood serum; *b* is a portion of the same culture × 80 (after Koch).

The tubercle bacilli are frequently beaded; they may occur singly, or in pairs, or in bundles. The bacilli are always rounded at the ends (see Fig. 51). They are non-motile, do not liquefy the culture medium, and form spores both within the body and in artificial cultures. With regard to the latter Crookshank[1] remarks that "the tubercle bacillus, when examined by such powers as Powell and Lealands $\frac{1}{25}$ in Hom. imm. is frequently seen to consist of a very delicate sheath, holding together a number of deeply stained granules, for the most part round or cylindrical, with irregular contour and differing considerably in size, while the light interspaces are seen to vary in form according to the shape of the granules. In some preparations more distinct and clearly ovoid granules may be observed which are sometimes terminal. It is not impossible that these ovoid granules are spores which in their behaviour to staining reagents thus form an exception to the general rule. But there can be little doubt that a tubercle bacillus consists for the most part of a very delicate sheath, with protoplasmic contents which have a great tendency to be broken up or coagulated into little segments or roundish granules, owing, possibly, to the treatment they are subjected to in making a microscopical examination. This, however, does not always occur, for the bacilli at times are not beaded, but are stained in their entirety."

FIG. 51.

(346) *Artificial Cultivation of Tubercle Bacilli.*

Koch found the most suitable medium in which to cultivate the bacilli was blood serum coagulated at a temperature of 65°; it remains transparent if this heat is not exceeded. He sterilises it by heating for five alternate days for one hour each day,

[1] *Manual of Bacteriology.* 2nd edition.

PLATE III

Clark, Edinburgh

this treatment always gives sterile serum; he then coagulates at 65°.

The bacilli infected into such a soil show no change when the culture is maintained at 37° (which is the best temperature) for many days, it is not indeed until from the tenth to the fifteenth day that changes are evident to the naked eye. The first sign is little whitish points, these increase and are wholly made up of colonies of the bacilli; the bacilli are arranged more or less with their long axis corresponding with that of the colony itself, with a space between the individual bacilli. But the most characteristic appearance is that of the arrangement of the colonies—when examined by a low power, they are either in S shapes or in such curious curves as to recall the flourishes of fancy letter writing. In old growths these appearances are lost from the blending and massing of the colonies together.

Baumgarten [1] proposed to inoculate, with antiseptic precautions, tubercle containing bacilli into the anterior chamber of the eye of a rabbit; after from six to eight days the affected part of this anterior chamber is to be inoculated into a second rabbit. By a repetition of this process several times, an absolutely pure cultivation free from all admixture of foreign germs can be obtained.

Nocard and Roux [2] recommend the addition of 6 to 8 per cent. of glycerin to blood serum or agar-agar as very suitable for the growth of the tubercle bacillus. Tubercle bacilli are also said to grow well in broth containing equal parts of glycerin and peptone.

Hueppe [3] gives a process by means of which the tubercle bacilli may be cultivated in blood serum, and isolated by the method of plate cultivation. Fluid blood serum, either sterilised or collected germ free, is warmed to 37° C. in the ordinary way, and then equal parts of agar-agar solution is added (2 per cent. agar broth with 5 to 10 per cent. grape sugar), the whole is mixed by shaking, poured on to a plate, and incubated.

Pawlowsky[4] has succeeded in cultivating the tubercle bacillus on potatoes. Koch had declared that the bacillus only developed on animal substances and had failed to raise it on potatoes.

[1] *Centrl. f. d. med. Wissen*, 1884.
[2] *Annales de l'Institut Pasteur*, 1887.
[3] *Central. f. Bak. u. Parasit.* Bd. I., No. 20.
[4] *Annales de l'Institut Pasteur*, No. 6, 1888; and *Public Health*, vol. i.

(347) *The Universal Presence of the Bacilli in True Tubercle.*

Baumgarten,[1] almost contemporaneously with Koch, succeeded by treating sections of tubercle with very dilute soda solution or potash, in demonstrating bacilli. The identity of these with Koch's bacilli was at a later date established. Baumgarten drew the conclusion from his researches that bovine tuberculosis, human tuberculosis, phthisis, and scrofula belonged to a single species of disease.

Weichelsbaum (*Archiv f. exper. Pathol.* Bd. XVII.) also tested the views of Koch as to the presence of the tubercle bacilli in human tubercle and as to their pure cultivation, as well as the opposite views of Spina; he obtained the same results as Koch. At the same time he recognised the difference between the small nodules excited by indifferent bodies and those caused by infection from tuberculous products or pure cultivations.

Koch pursued his researches with such ardour and so thoroughly that there has been little left for others to discover save in matters of detail. He found the bacilli most numerous in miliary tubercle; in cheesy bronchitis and cheesy pneumonia; they were extraordinarily numerous in the contents of cavities, shreds from which were almost wholly composed of them. He also found them several times in scrofulous glands, in the fungus granulations of joints; he also recognised them in bovine tuberculosis as well as in the spontaneous tubercle of pigs, fowls, monkeys, rabbits, and guinea-pigs; they were likewise constant in a number of cases in the inoculated tubercle of rabbits, guinea-pigs, and cats. He also found the bacillus in lupus and was able to cultivate it from thence artificially. The constant presence of the tubercle bacilli in tuberculous organs having been ascertained, he turned his attention to their culture and to the production of tuberculosis through the inoculation of the cultures. This requirement was also fully attained; out of these products new cultures were made which had the same action on animals. Since the tubercle bacillus only grows between 30° and 40°, Koch declared it a true parasite which obtained entrance into the animal organism mostly through breathed air adhering to particles of dust. In phthisical sputa

[1] *Central. f. d. Med. Wissenschaft,* No. 15, 1882. *Deutsche Med. Wochenschrift,* No. 22, 1882.

Koch found great numbers of tubercle bacilli, and since, after several weeks' drying, the sputa still retained its infectious character, it was the most common source of the infection, but the flesh and milk of tuberculous animals also played a part.

(348) *Experimental and Clinical Proofs of the Contagious Nature of Tuberculosis.*

A number of physicians have collected evidence from their clinical experience to prove the contagiousness of tuberculosis, *e.g.*, Meyerhoff,[1] T. Demuth,[2] Faisan,[3] Lindmann[4] (tubercular infection from the operation of circumcision), Herterich,[5] Dehove,[6] Ogston,[7] Alison,[8] Potain,[9] L. Langer,[10] Krasker,[11] Bonyer,[12] Webb,[13] Martin,[14] Ganett,[15] Wahl,[16] Leser,[17] Schmidt[18] (tuberculosis infection from a kiss), and others. To these also belong cases of the so-called infectious tuberculosis of men, in Finger's[19] comprehensive description of lupus and tuberculosis.

De Lamalleree[20] cites a case in which a person became infected through eating a half-cooked fowl which had itself become tuberculous through consuming with its food phthisical sputum.

Among pathologists, Koch's doctrine found more ready acceptance, most of them repeated his experiments either in single points or generally, and were convinced of their accuracy. Many of these researches do not appear in literature because, being simply confirmatory of Koch's results, their communication was considered unnecessary. Of the published works confirming Koch's results the following may be mentioned :—

Watson Cheyne,[21] who had worked partly under Koch's instruc-

[1] *Zeit. f. klin. Medicin.* Bd. VII. [2] *Bairisches ärtzl. Intelligenzblatt.* 1883.
[3] *Progrès méd.* 1883, Nos. 34 and 38.
[4] *Deutsche med. Wochenschrift.* 1883, No. 30.
[5] *Bairisches ärtzl. Intelligenzblatt.* 1883, No. 23.
[6] *Public du Progrès méd. Paris.* 1884.
[7] *B. Med. Journal.* 1884. [8] *Arch. gén. de Méd.* Paris, 1884.
[9] *Rev. de Méd.* 1885. [10] *Wiener med. Wochen.* 1885, Nos. 15 and 16.
[11] *Centralblatt f. Chirurgie.* 1885, No. 47.
[12] *L'Union méd.* 1885, No. 71.
[13] *Philadelphia Med. and Surgical Reporter.* 1885.
[14] *Revue d'Hygiéne.* Bd. VIII. [15] *Boston Med. and Surgical Journal.* 1886.
[16] *Archiv. f. klin. Chirurg.* Bd. XXXIV.
[17] *Fortschritte der Medicin.* 1887, No. 16.
[18] *Ein Fall v. localer Impftuberculose. Dissert.* Leipzig, 1887.
[19] *Central. f. Bakteriologie u. Parasiten.* Bd. II., Nos. 13 and 14.
[20] *Gazette méd de Paris.* 1886, No. 32. [21] *Practitioner*, 1883.

tion, confirmed in all details the work of the latter; whilst he never failed to excite tuberculosis in animals with a pure culture of Koch's bacillus, he could never succeed with Toussaint's microbe. The manifold appearances which are seen in the lung in tuberculous infection, he sought to explain by the differences of growth of the bacillus when inhaled into the lung; a strong development giving rise to a cheesy, a weak to a fibrous pneumonia.

Raymond and Arthaud,[1] on testing Koch's discovery as well as Pasteur and Koch's method of culture, came to the conclusion that Koch's bacillus was actually the cause of tuberculosis, they also found that the tubercle bacillus throve well in rabbit broth and meat extract at 25°, but the growth was slow. Celli and Guarineri[2] confirmed on the one hand the presence of tubercle bacilli in phthisical sputum and in several tubercular organs, on the other they obtained, by inoculating the anterior chamber of the eye of rabbits with tuberculous products (such as phthisical sputum, cheesy masses from a tuberculous pleuritis and scrofulous glands), processes in which they could recognise tubercle.

Baumgarten,[3] to prove the pathological significance of tuberculosis, placed in the anterior chamber of the eyes of rabbits pieces of tuberculous tissue. After a few days he could recognise the growth of the bacilli in the cornea and iris; by the tenth and eleventh day a tubercle visible to the naked eye could be seen in the iris. In the fifth week the kidneys were affected, and in the neighbourhood of the glomeruli there were colonies of bacilli.

Poten[4] met the objection that experimental tuberculosis was confined to miliary tuberculosis and not to phthisis, by successfully exciting in animals processes closely resembling cheesy pneumonia and human phthisis from the introduction into the trachea of particles of tubercle and the products of artificial cultivations.

Weichelsbaum[5] also by means of powdered dried tuberculous sputum made inhalation experiments on dogs. The experiments showed that whether the inhalation was made once or many times

[1] *Arch. gén. de Méd.* Bd. I. [2] *Gaz. d'Hospit.* 1883, Nos. 37 and 40.
[3] *Central. f. die med. Wissen.* 1883, No. 42.
[4] *Exper. Untersuchungen über Lungenschwindsucht u. Tuberculose, Dissertation, Gottingen.* 1883. [5] *Wiener med. Jahrbucher.* 1883.

there was constantly, after one or two weeks' incubation, a copious formation of tubercles in the lungs, frequently also tubercle in the bronchial glands and in the kidneys, which through their histological structure and the presence of the bacilli proved to be true tubercle, whilst with the inhalation of non-tuberculous substances only occasionally, or quite singly, small nodules appeared without the tubercle bacilli. In order to make the experiments more decisive, injections were made into the abdominal cavity of dogs of phthisical sputum, this was followed by an extraordinary development of tubercles, whilst after similarly injecting emulsions of cheese or boiled tuberculous sputum no change took place.

Before the discovery of the tubercle bacilli, Veraguth[1] had made inhalation experiments with tuberculous sputum, and he later extended them; half of the animals experimented on showed tuberculosis, whilst after inhalation of non-tuberculous sputum no microscopical change in the lungs could be discovered.

Kussner[2] introduced through an opening in the trachea of rabbits, tuberculous and non-tuberculous sputa; in the first case tubercle occurred in a gelatinous zone containing bacilli, in the latter no effect at all followed. Sternberg[3] opposed the contention of Formad and others, that through the injection of finely-divided inorganic substances tubercle could be excited. One to two months after the injection of coloured substances or pounded glass, he found the foreign substances rolled into balls and encapsuled, but never tubercle, Formad could himself be convinced of this.

Schmidt[4] and Bollinger[5] attempted a pure cutaneous infection by rubbing into erosions of the skin of the guinea-pig, substances containing tubercle bacilli. In this way no tubercle could be excited, but only by inoculation into the sub-cellular tissue or into the abdominal cavity, hence they concluded that tubercular infection through vaccination was improbable. On the other hand, Baumgarten[6] alleged that he had repeatedly succeeded in exciting

[1] *Mittheilungen d. Wiener med. Doct.-Kolleg.* 1883.
[2] *Deutsche med. Wochenschrift.* 1883, No. 36.
[3] *American Journal of Medical Science.* 1883.
[4] *Bairisches ärtzl. Intelligen.* 1883.
[5] *Zur Aetiologie der Tuberculose.* München, 1883.
[6] *Jahresbericht uber die Fortschritte in der Lehre v. d. pathogen Mikro-organismen.* 1886.

tuberculosis by rubbing in cultivations of the tubercle bacillus into cutaneous wounds. Cases of true cutaneous infection have been recorded in the human subject, for instance, Lesser[1] relates the case of a washerwoman who frequently washed the linen of her husband, who died of a tubercular affection of the lungs as proved by post-mortem examination. The woman presented herself at the same hospital in which her husband had died with a small tumour the size of a cherry growing on the wrist, this was extirpated and found to contain tubercle bacilli. Eight days after the operation the patient showed herself with a *perionychia tuberculosa* of the terminal phalanx of the left ring-finger. The skin appeared at different places as if it were worm-eaten and undermined by cheesy masses. After removal there was good recovery, but some slight rales could be detected at the apex of the right lung.

A similar case is described by Steinthal (*Deutsch. med. Wochen.* No. 10, 1888), and also one is described by Merklen (*Gaz. hebdom. de Med. et Chir.* 1885, 27). In the latter case a woman, 26 yearr of age, had nursed her phthisical husband for six months. She used to wash his linen and clean the spittoon. Two months after his death there formed on the back of her second finger a tubercular nodule. This, in four weeks, affected the lymphatics of the arm, and an abscess formed in which tubercular bacilli were discovered. The apices of the lungs also became affected. M. B. Schmidt (*Arbeiten aus der Chirurg. Poliklinik, Leip.* 1888) relates the case of a woman aged 44, who nursed her husband dying of phthisis. Before his death he bit her, as she was about to kiss him, on the upper lip. On the bitten part a tuberculous swelling developed. She also had, on the ulnar side of the little finger and the wrist, three characteristic tuberculous nodules in which, after excision, were found giant cells and tubercle bacilli. There are also cases in which medical men seem to have been infected in making post-mortem examinations of tuberculous subjects.

The tuberculous nodules which are sometimes to be met with in the face, more especially of children, are considered by Lesser as the seat of tubercle inoculation. He relates two cases. The first was a child three years of age which was brought to him with a red livid tubercle of a doughy consistence, situated on the point of

[1] *Deutsche med. Wochenschrift.* No. 29, July 19, 1888; *Public Health,* vol. i. 155.

the nose. This was removed; the wound quickly healed. Eight or nine months later the child suffered from caries of the tarsi. In the second case a nodule appeared on a boy's chin, and a few weeks later a tuberculous caries of one of the vertebræ followed. In cases of skin inoculation there is as a rule strong hereditary predisposition—that is, great susceptibility to take the infection.

Von Wehde[1] tested the infectious character of the air of rooms inhabited by the phthisical, by exposing plates wetted with glycerin, and then inoculating guinea-pigs with the dust obtained; but the latter remained free from tuberculosis, hence he concluded, the expelled air of the tubercular could not infect, and that also tuberculous sputum so long as it was moist released no spores. Celli and Guarnieri,[2] Sirena and Pernice,[3] and Nicolas,[4] obtained similar results. On the other hand, Theodore Williams,[5] by placing a glass smeared with glycerin for five days in a ventilating-shaft, at Brompton Hospital, was able to recognise the tubercle bacillus.

Sirena and Pernice[6] placed guinea-pigs in a flask in which powdered sputum was shaken up frequently, but neither by inhalation nor by injection into the trachea could they ever excite tubercle; inoculation alone was active. Celli and Guarnieri[7] could but exceptionally excite tubercle by inhalation experiments, only when the mucous membranes were previously irritated by breathing irritating gases.

The researches of Muller,[8] Truomi,[9] are also to be mentioned; both succeeded through the injection of tuberculous pus in the arteria nutritia tibiæ of goats, or by the introduction of tuberculous matter into the joints of rabbits, in causing typical tuberculosis of the bones and articulations. There are also to be remembered the researches of Spillmann and Haushalter,[10] and E. Hoffmann,[11] who succeeded in proving that the abdomen and the excrements of flies which suck the sputum of the phthisical, contain the tubercle bacilli, so that, therefore, flies may be the medium of tuberculous infection.

[1] *Bollinger, zur Aetiologie der Tuberculose.* München, 1883.
[2] *Gazzette d. ospit.* 1883.
[3] *Arch. f. Scienz. Med.* Bd. IX.; *Gazz. d. ospit.* 1885.
[4] *Union Med.* 1886, No. 80.
[5] *The Lancet.* 1883.
[6] *Ibid.*
[7] *Estr. d. Atti. Acad. Med. di Roma.* 1886.
[8] *Zeit. f. Chirurgie.* Bd. XIV.
[9] *Giorn. internation. d. Scienz. Med.* 1886.
[10] *Compt. Rend.* T. CV.
[11] *Public Health*, vol. i. 220.

E. Hoffman artificially fed flies with phthisical sputum with a positive result; they became feeble, with increase of the excreta, and soon died. The intestinal contents of infected flies inoculated into the anterior chamber of the eyes of nine guinea-pigs gave positive results in five cases.

(349) *The Production of Tubercles in Animals by Feeding them with Tuberculous Products.*

Wesener[1] made a number of researches on the production of tubercle in rabbits from food; for this purpose he used sputum fresh or putrid, or after treatment with various digestive fluids. The feeding was exclusively milk with the addition of alkali. The result was always positive with simple feeding by fresh tuberculous sputum, so also with dry and putrid sputum, tuberculosis of the mesenteric glands being first produced, and next that of the intestine liver and spleen. Direct injection into the intestine much accentuated the process. Treatment of the sputum with different digestive fluids, drying, and putrefaction, did not destroy the infectious matter. Wesener thought that the spores preserved their characters when the bacilli were destroyed in the stomach. If the number of spores is so small that the lymph apparatus can get rid of them before they multiply, no infection occurs; if a larger number remain in the mesenteric glands, an inflammatory centre at first forms without bacilli, later these farther develop, but if the bacillary material is injected direct into the intestine, very soon tuberculosis of the intestine is produced. Tuberculosis of the mesenteric glands he refers also to the ingestion of milk with few spores.

Fischer[2] and Baumgarten[3] partly arrived at other results than Wesener, they could by once feeding with milk to which had been added tuberculous juice, excite tuberculosis of the intestine, the mesenteric glands and liver of rabbits. They farther assert that the tubercle bacilli when spore free withstands the action of the digestive juices. In opposition to Wesener's results they found

[1] *Kritische u. exper. Beiträge zur Lehre v. d. Fütterungs-Tuberculose.* *Freiburg*, 1885.
[2] *Archiv. f. exper. Pathol.* Bd. XX.
[3] *Centralbl. f. klin. Med.* 1884, No. 2.

that the intestine was first affected with tuberculosis, and subsequently the mesenteric glands. The unwounded mucous membrane of the mouth and throat could absorb tubercle bacilli in the food by means of the lymphatic apparatus.

Professor Straus placed, during from one hour to forty-eight hours, spore cultures of the bacillus of Koch in contact with the pure gastric juice of a dog. After six hours the bacilli had lost none of their virulent action. After twenty-four hours this action was destroyed. It may thence be seen that the tubercle bacilli are not rendered inoffensive by their sojourn in the stomach. Nevertheless, the gallinaceæ appear to be rarely infected with tuberculosis through the intestinal canal. M. Straus had given daily to fowls during several months, enormous quantities of the sputa of phthisical subjects. In none of the fowls was there any trace of tuberculosis, not even in those which in one year had swallowed as much as fifty kilogrammes of tuberculous sputa.

Bollinger[1] observed tuberculosis of the intestine, liver and spleen in three fowls which had fed on tuberculous sputa in the court of an hospital.

(350) *Unequal Susceptibility of Different Animals to the Tubercular Infection.*

In the numerous experiments on animals which have been made it has been found, as might be expected, that some are more predisposed to the infection than others, for instance Daremberg[2] draws from his researches the conclusion that in animals the tuberculosis produced by inoculation depends as to its character on the kind and age of the animal, as well as on the activity and quantity of the tubercle bacillus. If the tubercle bacilli are cultivated at 38° C., and introduced by trepannation into rabbits and guinea-pigs, the animals are killed in from twenty to thirty days by miliary tuberculosis; but in a cock and a dove treated in the same way, the first died in six or seven months. A culture at 50° excited in a rabbit only an indolent abscess, the pus of which killed young rabbits in several weeks, whilst old rabbits after some months showed no change.

[1] *Bayrisches ärtzl. Intelligenzblatt.* 1883, No. 16.
[2] *Compt. Rend.*, T. CV.

It has yet to be proved that any warm-blooded animal is exempt from tuberculosis; some, like the horse, rarely suffer from this malady, but even in the horse spontaneous tuberculosis is not extremely rare, and cases have been described by Johne, Coker, Nocard, M'Fadyean, Campbell, and Freer.

(351) *Giant Cells.*

Koch was of opinion that the beginning of tubercle was the entry of a bacillus into an epithelial cell, which cell may wander from its original seat. The pathogenetic action of the bacillus causes changes in the surrounding cells. The epithelial cell itself is converted into a "giant cell." This account of the origin of giant cells is much disputed, some see in the giant cell a lymph space with proliferating endothelial cells. In some cases Weigert has proved that the giant cell is a collection of cells in which bacilli are causing proliferation at the margin and fusion and degeneration in the centre, the end result being a mass of caseous material in the centre and at the margin proliferating cells with bacilli between them. Klein has seen giant cells produced by the fusion of the epithelial cells of the air vesicles. Small blood vessels, the seminiferous and the lacteal tubules have all been described as developing into giant cells. "The presence of these giant cells affords evidence that the cells are making a determined resistance against the advances of the bacilli, are giving way slowly, and so limiting the area of caseation. In many cases where the giant cells with their rings of nuclei are best marked, very few bacilli are to be found, as they have been destroyed by the phagocytes at the margin—*i.e.*, the active cells with deeply stained nuclei. In other cases, however, the bacilli have taken the place of the nuclei at the margin of the giant cell, the boundary line in such cases being determined for a time by the basement membrane of the tube in which the mass is formed."

Once the tubercle bacillus gains access to the deeper tissues, it depends on two things whether the bacilli will infect or no, viz. (1) on the numbers of the bacilli themselves, and (2) on the tissue resistance. Should they arrive in large numbers, few tissues will resist the invasion; should they arrive in moderate numbers, the

R & R. Clark, Edinburgh

so-called susceptible individuals will be affected, while those with healthy tissues with normal or a high resistance will be able to destroy or to localize the invading host.

(352) *Pathology of Tuberculosis.*

Some of the naked eye appearances of tubercle and tuberculous ulceration are represented in plates II, III, IV—

Plate II (*c*) represents the spleen of a guinea-pig affected with general tuberculosis from the injection of a culture into the anterior chamber of the eye (after Koch).

Plate III (*c*) represents the lungs of a guinea-pig infected by inhaling dried tuberculous sputum (after Koch).

Plate IV (*b*) is a portion of the small intestine from a Cariama (*Cariama cristata*), the blood-vessels of which have been minutely injected. It exhibits very small masses of tuberculous matter raised a little above the surface of the mucous membrane. The paleness of the tuberculous matter contrasts strongly with the bright redness of the mucous membrane (Royal College of Surgeons Museum. No. in Catalogue 2,546). (*c*) represents a tuberculous ulcer in the human ileum. The surfaces are but little indurated though very vascular, and the floor of the ulcer presents a yellow caseous appearance. There are also several small tubercles (Royal College of Surgeons Museum. No. in Catalogue 2,547).

Both these ulcers may be compared with (*a*), which represents a portion of the human ileum affected with a typhoid ulceration of one of Peyer's patches (Royal College of Surgeons Museum. No. in Catalogue 2,499).

The pathology may be studied conveniently under two divisions, viz., that of pulmonary tuberculosis and that of miliary tuberculosis. The most recent contribution to and summary of the pathology of the disease is the research of Dr. Sims Woodhead, and the following account is an abstract of Dr. Woodhead's paper on the subject.

(353) *The Pathology of Pulmonary Tuberculosis.*

It is now generally accepted that all cases of rapid infective phthisis are the result of the action of the tubercle bacillus,

although it cannot be denied that certain lesions may be produced as the result of the action of other non-specific irritants. In these conditions, however, tubercle is very frequently associated with some other lesions, and it is often extremely difficult to say what changes are due to the one and which to the other. For instance, it has long been held that in stonemasons' phthisis all the characteristic lesions met with in chronic tubercular phthisis are present, but Dr. Woodhead's experience of stonemasons' lung has been that along with the chronic interstitial and arterial changes, set up by the stone particles, there are structural alterations which can be accounted for only on the assumption that they are of tubercular origin, and in some few cases, in confirmation of this, the presence of tubercle bacilli has been demonstrated in certain of the new growths. In the first instance we should expect under given conditions the mucous surface of the bronchus to be attacked. Such an assumption might most fairly be made after a consideration of Julius Arnold's observations on the course taken by dust when inhaled into the respiratory passages, Arnold pointing out the important part played by the walls of the small bronchi and their terminal passages in the disposal of inhaled dust particles. Secondly, there is the alveolar epithelium, which under the influence of any irritant material undergoes proliferation more or less rapid, this in certain cases terminating in what we know as catarrhal pneumonia. Here, again, in proof of the statement, take what may be seen under the microscope, when particles of coloured dust have been inhaled into the lung. The cells lining the alveoli are seen to be in an active state of division; some are still adherent to the walls of the air vesicle, and in these small particles of the pigment may be seen embedded in the protoplasm. The epithelium in this position is a structure which may be attacked by tubercle bacilli, just as in it coal or other particles may be found. Passing still further, and following the course taken by the pigment granules, the lymph spaces around the air vesicles are reached, then the lymphatics in the interstitial and interlobular tissue, the peribronchial and perivascular lymphatics, and lastly the glands at the root of the lung, either directly or by deep layer of the pleura, over the surface of the lung, and so to the root. As may be seen on reference to a section of coalminer's lung, the pigment (in this

instance a material which gives rise to little irritation) is carried to every part of the lymphatic system, and is seen to have accumulated in very considerable quantities along the lines of the septa, around the bronchi and bloodvessels, and in the deep layer of the pleura. On microscopic examination, the pigment acting as an irritant, and so giving rise to a slight excess of fibrous tissue in all these various positions, may also be seen. Lastly, the small points of lympathic tissue which occur at intervals along the lymph channels, first described by Burdon Sanderson, then by Klein, Arnold, and others, are the seats of pigmentation. Tubercle formation may also be met with in any of these positions. It would seem at first sight to be an easy matter to determine at once in what tissue the tubercle has originated in any special case. In the lung, however, where the tissues are so delicate and so complicated, and where in consequence the changes are so rapid, this is not the case; and it is only in exceptionally favourable cases that the mode of origin and spread can be at all satisfactorily demonstrated. Further, the variety in the life histories of individual tubercular growths at one time rendered it a matter of considerable difficulty to arrive at any definite understanding of tuberculous processes, especially of those associated with pulmonary phthisis. The anatomical structure in the various forms being so absolutely defined in the earlier stages of the growth, it was difficult to bring into a common group forms which differed so widely from one another, not only in naked eye but in microscopic appearances.

There is now, however, sufficient evidence to justify pathologists in stating that many of those forms which different clinical observers have from time to time described as tuberculous are undoubtedly tubercular in character, from the small grey, gelatinous, or fibroid nodule, to the large caseous masses, leading to cavity formation; and the presence of the specific bacillus has time after time been demonstrated in all these forms, both by staining and by inoculation. There can be little doubt that these forms are essentially the same, and that the differences observed are due first to the resisting power of the tissue attacked, and secondly, to the numbers and activity of the attacking bacilli. If the behaviour of other tissues under the action of mechanical or micro-organismal irritants be borne in mind, there will be little cause for wonder

that there should be these numerous varieties of manifestation of the action of the specific irritant in tuberculous lungs. In connection with this statement, a matter may be insisted upon to which, as a rule, far too little importance is assigned—viz., the intercurrence of suppurative changes, which are evidently set up by the activity of a different micro-organism.

Both Dr. Woodhead and Mr. Hare were much struck by the fact "that after one micro-organism has completed its task another may step in and continue the process of breaking down. How frequently a pyæmic condition supervenes on a tubercular. How often has a patient suffering from tubercular abscess of the kidney or of the lungs succumbed at last (if not carried off by acute tubercular disease) to pyæmia, and pyæmia in which the symptoms are extremely well defined."[1] How frequently localized suppuration steps in to aid in the breaking-down process, more frequently in the lungs and in the intestines than in other positions, because of the greater ease with which organisms giving rise to the irritant material can arrive at and remain on the tubercular surfaces in these organs. Writing on this subject, Coats, in his Lectures to Post-graduates, points out that tubercle is essentially a disease of surfaces and channels, and this is so far true that bacilli can reach the tissues only by such surfaces and channels, and that in these channels there are irritant secretions often containing numerous micro-organisms and other products which assist in completing and hastening the breaking-down process commenced and partially continued by the tubercle bacilli. The actions and interactions in these cases are extremely complicated, and but for the occurrence of more simple cases now and again the observer would be completely lost amongst it all. Of 100 cases, in which there was tubercle of the mesenteric glands, the mediastinal glands, or the glands at the root of the lung, were also distinctly affected in 69 cases, whilst in 62 cases the lungs themselves were affected. Of these 62, 59 were included under the 69 in which the glands at the root were tubercular, the other three having developed first simple catarrhal pneumonia, which had later become tubercular in character (in two of these bacilli were found). There were also, as the figures show, seven cases in which, although the glands at the root were affected, there was no tuberculous process in the lungs

[1] *Pathological Mycology*, p. 13.

This is important, for when the lung cases as a whole are considered, the figures are slightly different. Of 110 cases of tubercle of the lung, the glands at the root were not affected in every case this was especially noticeable in cases of miliary tubercle, and in several cases of catarrhal pneumonia. There were distinct tubercle nodules, and caseation in the glands, except in those cases where there had been adhesion of the lung at any point, or where there had been collapse of the lung. Where these conditions were present—*i.e.*, adhesion, collapse, etc.—the tubercle in the glands at the root was, in a much larger proportion of cases, of more recent date. In the 110 cases there were cavities in 32, caseous masses but no large cavities in 39, racemose tubercle with a tendency to fibroid change in 25, and tubercular catarrhal pneumonia in 15, in each case the character of the predominant lesion only being recorded. The cavities and caseous masses were not, as in the adult, usually confined to the apex, but were, as in monkeys and other animals, scattered throughout the lung—a fact which might be explained on the supposition that in such cases the general predisposing causes of tuberculosis are acting quite apart from those of local origin. Where these local predisposing causes do come into play, the seat of election in children is not at the apex, but at the root of the lung, very frequently posteriorly, and at the base.

The general tuberculous affection of the lung in children appears almost invariably to have associated with it one of three antecedent conditions :—

(*a*) Simple capillary bronchitis and catarrhal pneumonia, such as very frequently follow or are associated with measles, diphtheria, scarlatina, whooping-cough, and other similar conditions, in which there is a weakened condition and impaired power of resistance of the epithelial cells lining the capillary bronchi, the alveolar passages, and the air vesicles; further, there are those interstitial changes in connection with the lymphatic network mentioned previously; and, lastly, there is the irritable (speaking now of the proliferating tissues of the gland) and weakened condition of the glands, both the small collections of the glandular tissue along the lines of the lymphatic channels and the larger glands at the root of the lung. Not only is the resisting power less in these conditions, but owing to the large amount of work they have been called upon to do in connection with the absorption of the catarrhal

products, the glands, though enlarged and swollen and evidently acting most vigorously, are unable to respond to any increased demand for work, either in taking up or destroying fresh *materies morbi.* In a case of tubercular catarrhal pneumonia, following typhoid fever, the greater part of the lung, especially the lower lobe and the lower part of the upper lobe, was consolidated; it was grey in colour throughout, was not firmly consolidated as in croupous pneumonia, but was slightly more spongy in texture. From the cut surface a large quantity of purulent fluid could be squeezed, in which were present very large numbers of tubercle bacilli. On section the air vesicles throughout, but especially around the terminal bronchi, were filled with large proliferating epithelial and catarrhal cells, some in an advanced stage of degeneration, but others containing well-marked bacilli in and around them. Although in this case the interstitial changes were not very prominent, there were nevertheless numerous bacilli in the lymphatics, some free, but many contained in the small round corpuscles found there; and, again, a few bacilli were to be distinguished in the lymph sinuses in the cortex of the glands. In the medullary portion of the gland there was evidently rapid cell proliferation, but little or no caseation. In several other cases of catarrhal pneumonia following diphtheria, scarlet fever, and measles, an earlier stage could be observed. In these conditions the lobular catarrhal pneumonia is frequently preceded by collapse in certain small areas, the result probably of closure of the bronchus with catarrhal products of the bronchus itself. In these plugs, and in such cases as these only, large numbers of tubercle bacilli were found; they were so numerous that the idea of their having all come originally from some other definite tubercular focus was put out of court entirely, and their presence in such large numbers could only be accounted for on the supposition that a few had first been introduced into the catarrhal mass, which had formed such an excellent cultivation medium that an almost pure culture of the bacilli in the small bronchi had resulted. In the air vesicles in the immediate neighbourhood, a few bacilli may also occasionally be seen, but in the larger proportion of these cases the bacilli are confined to the lumen of the bronchus. It may be readily understood how in such cases, had the patients lived long enough, the bacilli and their products would have made their way into the lymphatics,

and so to the glands; but the process is here extremely rapid, and caseation very speedily supervenes, this apparently being in great measure due to the lowered vitality of the tissues.

(*b*) Another form of this general tuberculosis of the lung is where there is inhalation of the specific virus from some localized nodule or mass. In adults the most common termination of a case of apical phthisis is brought about by a form of acute tubercular pneumonia in the dependent parts of the lung. The extreme consolidation and rapid caseation in such cases are here also well-marked features of the process. In like manner it is found that in children the general dispersion of the virus often takes place from a small cavity which eventually opens into a bronchus. In three cases Dr. Woodhead observed a second form of primary focus, one not very commonly recognized, but one of which a case is recorded by Dr. Coats in his Lectures to Practitioners, page 170. In two of the cases under consideration the glands at the bifurcation of the trachea were enormously enlarged and distinctly caseous, and at one point they were much softened; just above this softening there had been ulceration into the left bronchus near the bifurcation, and the contents of the softened glands had been practically emptied into the bronchus. As a result of this there were well-marked recent tubercular catarrhal pneumonic patches, swarming with bacilli, throughout the lung, but accompanied by interstitial tubercular changes, although bacilli could be demonstrated as present in the lymphatics. In these cases the catarrhal condition is evidently tuberculous from the first, and the process goes on with extreme rapidity. In the third case, one of the smaller glands at the root of the lung was the infective focus, the ulceration having taken place in one of the larger branches of the left bronchus. A third form of ulceration met with and giving rise to a disseminated catarrhal tubercular process, is that where the wall of the bronchus itself is tubercular, and where in consequence there is ulceration and setting free of the infective material in smaller or larger quantities. This form is very frequently met with, and is a cause of tubercular catarrhal pneumonia in a very large number of cases.

(*c*) The third of the antecedent conditions of general catarrhal tubercular pneumonia is that condition in which the lymphatic glands at the root of the lung and the mediastinal glands are

practically inactive. This occurs specially when the tubercular glands are caseous, but it may also occur in other conditions, where the glands are either altered in structure or are choked (if such a term could be used) by the presence of foreign particles. In these cases, where the nutrition of the tissues is greatly impaired, general catarrhal tubercle is frequently met with, but it is then almost invariably associated with chronic or more recent interstitial tubercle.

In localized tubercle the lymphatics seem to play a much more prominent part than they do in the general form, though here, again, the two forms, lymphatic and catarrhal, are so closely associated that it is difficult to say where the one ends and the other begins. The seat of election of tubercle in children is not at the apex, but near the root of the lung, posteriorly, at the free margins (in patches) or at the base. In those cases of tubercle at the root, the predisposing cause is, as has been pointed out, the tuberculous condition of the gland. The lymph stream in the lung cannot be looked upon as going constantly in any one direction, on account of the very free lymphatic anastomosis in various parts of the lung, and through this free anastomosis an area may be drained by another set of lymphatic vessels, even though its own proper vessels are occluded. Thus when a gland at the root of the lung becomes functionally inactive from its conversion into caseous tubercle, the lymphatics going directly to it from an area in the immediate neighbourhood are obstructed, and there are both impaired nutrition in and diminished excretion from this part. Although, however, the tissues in this area immediately around the gland have their lymph supply altered, the tissues outside the localized area are drained into the lymphatics (1) of the glands corresponding to these areas, and (2) into those which eventually find their way into the deep layer of the pleura, and so to the root of the lung; and it appears probable that in consequence of this "backward flow" the affected area may in certain cases give rise to a further extension outwards. Tubercle at the posterior part of the lung and at the free margins is to be associated with obstruction and collapse, conditions so frequently met with in children and so common a cause of simple catarrhal pneumonia. The essential conditions necessary for tubercular catarrh and impaired lymph discharge are present,

and the bacilli, left at rest, develop very rapidly in the air vesicles, or more slowly in the lymph spaces in the interstitial tissue. Tubercle at the base of the lung is found especially in those cases where there is pleurisy, or in cases of peritonitis, tubercular or not. Of the cases analysed (127) the liver or spleen, or both, were adherent to the under surface of the diaphragm in sixty-five cases, most frequently as the result of old peritonitis, now without a trace of tuberculous structure remaining; but in seventeen, recent tubercular peritonitis was well marked. In a very considerable number of cases where old pleurisy was present, the base of the lung was markedly tubercular. In four instances the lower part of the lower lobe was transformed into a solid caseous mass, whilst in the fibrous tissue of which the adhesion was composed there were well-marked tubercular nodules, some quite young, but others in an advanced stage of caseation. In these cases the extension is, in the first instance, by the lymphatics, and then perhaps to the epithelium; but the predisposing cause appears to be the state of rest induced by the adhesions of the organs of the abdomen and thorax to the opposite surfaces of the diaphragm, leading to imperfect lymphatic circulation and exchange.

In the case of tubercular peritonitis, in which caseation occurs at an early stage, it might reasonably be expected that tubercular pleurisy and mediastinal tubercle would be rapidly developed. Professor Klein and Dr. Hunter have both laid great stress upon the fact that foreign materials which find their way into the abdomen are soon passed on to the under surface of the diaphragm; and Dr. Hunter, in his experiments on the absorption of injected blood from the abdomen, demonstrated most clearly the presence of blood corpuscles, comparatively little altered, first between the liver and the diaphragm, and secondly in the lymphatics of the diaphragm. The bearing of this on the adhesions of the liver to the diaphragm are exceedingly important, as are also Klein's observations on the paths taken by foreign particles after passing from the abdomen. Bearing these facts in mind, it may be easily understood how it is that tuberculosis of the mediastinal glands and tubercular pleurisy of the costal pleura are both so frequently associated with tubercular peritonitis. The glands, too, at the root of the lung frequently (as seen in so many specimens) become caseous before the lung itself is affected; in some cases,

no doubt, this is due to a process similar to that described as occurring in the mesenteric glands, where it is accompanied by no permanent lesion in the intestine; but in other cases it seems to be equally beyond question that the specific virus has passed (*a*) from the mesenteric and retro-peritoneal glands, and (*b*) from the peritoneal cavity through the central part of the diaphragm and the broad ligament of the lung, or (*c*) by a more or less circuitous route along the lymphatics of the parietal pleura to the root of the lung. It is worthy of note that until pleurisy is set up in these cases there is no transmission from pleura to pleura, but that as soon as the slightest adhesion takes place there may be continuation of the process on the two surfaces. It should be observed, however, that in addition to this affection of the costal pleura the visceral pleura may also be the seat of tubercular nodules, the virus in this case having come probably from the abdominal cavity by the diaphragm and the broad ligament. In all these forms there is abundant evidence of the transmission from point to point of the virus by way of the lymphatic channels, especially where the tissues generally are highly resistant, and where the epithelial cells, though they do not arrest the passage of the bacilli into the lymph spaces, have still sufficient vitality to continue to grow in a more or less regular manner. In such cases the connective tissue resistance is also great, and though the bacilli may still continue to grow and to attack the cells in their immediate neighbourhood, those cells outside the immediate sphere of action of the irritant are stimulated into proliferation and fibrous tissue formation, so that a fibroid capsule is formed around the cellular or caseating centre. When the epithelium itself is attacked caseation rapidly ensues, and absorption from this point may take place for some distance along the lymphatics. In consequence of this method of spreading by the lymphatics of the lung, nodules may be sought in those positions in which coal pigment is found to accumulate, the only difference observable being that in tubercle the nodules are usually somewhat limited in their area of distribution, the pigment, on the other hand, being disseminated over the whole lymphatic area. The changes around the vessels and in the bronchi are marked by no special features; the tubercles are formed in connection with the peri-bronchial and peri-vascular lymphatics, and in some cases, as has been

observed, they appear to be formed in the small lymphoid nodules which may be seen in the walls of the lymphatic vessels.

In the intima of the vessels, as Cornil and Ranvier, Hübner Greenfield, Hamilton, and others have insisted, the changes are extremely well marked, and quite recently attention has been called to the fact that even some of the systemic arteries may be deeply affected with arteritis obliterans in cases of chronic phthisis. How far the changes in the intima are associated with those in the adventitia is as yet not fully decided, but there seems every reason to hold with Arnold, that wherever the lymphatic circulation in the adventitia is disturbed—especially where there is irritation and proliferation of the endothelial cells of the lymph spaces—corresponding changes are met with in the intima, particularly where the process is chronic in character.

(354) *The Pathology of Acute Miliary Tuberculosis.*

Acute miliary tuberculosis must be looked upon as the result of spreading of the infective material directly by the blood channels. The demonstration of this fact was first accomplished by Weigert, who, in a series of several cases of acute miliary tuberculosis, was able to determine the presence of ulceration of the pulmonary vein. The process being similar to that in or near the wall of a bronchus in the cases mentioned, Ponfick had first supposed that the bacilli might pass from a tubercular thoracic duct into the venous trunks, and thus to the general circulation. It is probable that both observers were correct, and that both forms may occur. Coats further points out that a limited distribution of tubercle by the blood may be due to the passage of bacilli into the minute venous radicles in the glands in which tuberculous changes are occurring. That bacilli are found in the blood has been now frequently demonstrated, and quite recently several cases have been recorded, in which general tuberculosis has come on after hæmorrhages in patients suffering from apical phthisis. This is a matter of all the greater interest when it is borne in mind that all these cases of acute tuberculosis were developed in from seventeen to twenty-five days, just the period given by Koch as that required for the development of tuberculosis when produced experimentally. The importance of this can scarcely be over-estimated from a

surgical point of view, indicating as it does the methods of procedure to be adopted in operating on any tuberculous part. The bacilli, though found in the blood in such cases, do not become active until they come to some part of the circulation at which they can make their way into the surrounding tissues. In some cases bacilli are present in the emboli, or they may be actually distributed in the embolic area, in many cases appearing to make their way from the capillary vessels into the lymph spaces, and only then giving rise to the characteristic series of changes.

(355) *The Relations of Scrofula, Lupus, and Tuberculosis.*

The recent research of Dr. Alfred Lingard[1] shows the precise relationship of these affections. They must all be classed as tuberculous. Scrofulous material injected into a guinea-pig produces a general tuberculosis; lupus material does the same thing, but slower. In fact, given tubercle, scrofula, and lupus, there is a regular gradation of virulence, as tested by subcutaneous inoculation into guinea-pigs; with tubercle, in six or seven days the glands enlarge; with scrofula, the enlargement of the glands just above the inoculated point is not observed for two or three weeks; and with lupus, 28 days is the earliest time within which this has been noticed. Tubercle kills a guinea-pig in an average period of 80 days; scrofula, 206 days; lupus, 331·5 days. It is pretty certain that scrofula and lupus may be considered as the expression of different stages of attenuation of the tubercle bacillus, but by successive removes the bacillus acquires its pristine energy; thus, according to Lingard's experiments, if a guinea-pig be inoculated with scrofulous material, and the period in which it lives be reckoned as 100 days, products from this guinea-pig, injected into a second, kill in 63 days; inoculation from the second into a third guinea-pig kills in 38 days; and inoculation from the third into a fourth kills in 29 days.

(356) *Propagation of Tubercle through the Agency of Milk derived from a Diseased Cow.*

There have been numerous researches upon this important

[1] Supplement, containing Report of Medical Officers, to *Eighteenth Annual Report of the Local Government Board.*

subject. Johne[1] maintained that the milk of tuberculous animals should not be given to sucklings, and should not be consumed by any one when the teats were affected. The flesh of tuberculous animals may be eaten if the tuberculosis is not general, but the internal organs affected and the lymphatic glands are to be put on one side. In general tuberculosis the flesh also was not to be eaten. Lydtin[2] made experiments with the raw and boiled milk of tuberculous cows with and without udder affection on guinea-pigs, and obtained only once with raw milk a positive result, hence he thinks that the danger of infection through milk cannot be great, and through boiling can be quite avoided.

Martin[3] has experimented with Paris milk, derived from thirteen different dairy farms, by injection into the peritoneum of guinea-pigs. In one case general tuberculosis supervened. Stein[4] obtained a positive result in several instances by injecting the milk of tuberculous cows into the abdominal cavity of guinea-pigs, although in one only of his cases was the udder affected. The Commission[5] appointed in Victoria to inquire as to the extent of tuberculosis gave an opinion that the meat of animals strongly affected with tuberculosis should be forbidden, but in less severe cases could be consumed. On the other hand, tuberculous cows should be rigorously excluded from supplying milk for consumption.

Quittel[6] declared the use of flesh actually tuberculous, not fully boiled or cooked, injurious, but the meat of a tuberculous animal only injurious if the animal has become thin, and more than one organ is affected.

Bang[7] found the milk in cases of tubercle of the udder always to contain the specific bacillus, and it constantly produced tuberculosis. The milk of tuberculous cows with healthy udders sometimes contained tubercle bacilli, and then could produce tuberculosis; sometimes it was free from bacilli, and then inoculations were fruitless. In bacilli holding milk submitted to the centrifugal apparatus, for the most part bacilli could be recognised in the

[1] *Deutsche Zeitschrift f. Thier. Medicin.* Bd. IX.
[2] *Archiv. f. Thierheilkunde.* 1884. [3] *Revue de Médecin.* 1884, No. 2.
[4] *Experimentelle Beiträge sur Infectiositat perlsüchtiger Kühe. Dissertation.* Berlin, 1885. [5] *Report,* 1884–5.
[6] *Deutsche Vierteljahr. f. offentl. Gesundheit.* Bd. XIX.
[7] *Tidsk. f. Landœkonomi.* 1886.

scum at the periphery of the apparatus, the cream also contained single bacilli. Cream raised by standing was infectious, and the same must be said of the butter. Heating bacilli holding milk to 70 deg. C. destroyed mostly the infection, but not always. Boiling was constantly successful in destroying the infection.

Galtier [1] concluded from his researches that not only the raw or coagulated milk from tuberculous cows could infect, but also the cheese or whey prepared from it. He also calls attention to the fact that fowls or pigs could be infected from feeding on such substances.

At the International Medical Congress in Copenhagen, Bang gave the results of an examination of no fewer than twenty-seven cases of tubercular mammitis, and he was able to demonstrate the presence of tubercle bacilli in the milk or in the sediment, and with this milk or sediment he was able to produce tuberculosis both by inoculation and by ingestion. Nocard was able to demonstrate the presence of the specific bacillus in milk in eleven cases.

Dr. Woodhead has made a most careful and systematic examination of over 600 cows in the Edinburgh dairies with Professor MacFadyean. Of the whole, they found thirty-seven beasts in which there was mammitis, but only six, or 16 per cent., in the milk of which they could demonstrate the presence of tubercle bacilli, and then only in small numbers. In one of the six cases, and subsequently in five other cases, they made sure of the existence of the bacilli in enormous numbers in the udder by microscopic examination. They find that new tubercular tissue is disseminated in patches of various sizes throughout a portion of the gland, and that all the more minute elements of tubercle may be distinguished—the small round cells in which the nuclei are comparatively large, and the epithelioid cells, between or amongst which is a fairly well developed reticulum. The giant cells are very numerous, but are not so well defined as one sees them in the human subject; they are scattered throughout the new tissue. The tendency to caseation of tubercle in the udder is not nearly so well marked as in other parts of the body, but it does undoubtedly occur at points. The new growth of tuberculous tissue gradually invades the lobules of the gland, passing in along the lines of the

[1] *Compt. Rend.* T. CIV.

lymphatics of the interlobular septa, so that a gradual transition from the healthy gland substance to the dense tubercular mass may be seen. In the mass itself the characteristic bacilli are present in almost inconceivable numbers. They are seen first as small stained rings (masses of bacilli) around a slightly granular or homogeneous mass—in fact, the giant cells seem to consist of the *débris* of cells, the result of the activity of the bacilli. In the smaller cells bacilli may also be seen, and others may be demonstrated lying in the spaces between the cells. On careful examination of the more healthy parts of the gland, especially at the margin of the new growth, ulceration into the ducts may be made out. In consequence of the interference with the nutrition of the tissues immediately around the ducts or acini, the basement membrane has given way and a small mass of tubercular granulation may be seen projecting into the lumen; the epithelium is also proliferating. In the granulation tissue, in the epithelial cells, and even lying free in the lumen, there are frequently numerous bacilli, and it can be easily understood how, once in this position, they find their way into the milk. This ulceration is not, however, of such frequent occurrence as might be expected, for in the greater part of the gland substance left there is little or no catarrhal proliferation, and the ducts and acini appear to be obliterated in great measure by compression. In addition to these positions, bacilli could be demonstrated in epithelial cells still attached, and also in rare cases in those lying free in the apparently healthy milk ducts, in which position Professor MacFadyean had first demonstrated them. These facts, when considered along with the occurrence of bacilli in milk, with the feeding experiments recorded by so many observers, and the great prevalence of tubercle in certain classes of animals, go far to prove that milk is a source of tubercular infection, especially to young children. Cases are constantly cropping up in which pigs on dairy farms are affected with tuberculosis of a most typical character. Dr. Woodhead has recorded an outbreak (amongst pigs) on a dairy farm which could be distinctly traced to the milk of three cows in which the udders were markedly affected. All veterinary authorities concur in stating that cattle and swine are the two species in which genuine tuberculosis most frequently occurs. When it is remembered that on dairy farms, and even on farms where pedigree cattle (cattle which are very frequently

highly tubercular) are reared, the milk, especially that of cows suspected of disease, is given to the pigs, which often become tuberculous, it will appear in the light of recent researches that the disease is *propter hoc* rather than, as so many still hold, merely *post hoc.* It has often been objected, of course, that if all tuberculous cattle gave tubercular milk, the human race would run a risk of being rapidly exterminated; but it might now be maintained, as the result of most careful clinical observation, that it is only when the functions of the intestine are interfered with, and when, in consequence, there are temporary or permanent alterations in structure and in the chemical constituents of the fluids and gas in the alimentary canal, that tubercle bacilli can make their way unaltered through the epithelial barrier. The importance of Koch's experiments on anthrax and cholera bacilli, when ingested, cannot be over-estimated, and most of those who have followed him in this line of experimentation have come to the same conclusions on this point, however widely they may differ on others. It is not only the intestine itself, however, that is affected by these functional disorders. The mesenteric glands are also placed at a great disadvantage. This may be easily understood when it is remembered how the slightest irritation in any position is almost immediately followed by changes in the lymphatic channels and glands. Every one is familiar with the peculiar condition of enlargement, congestion, and succulence that is found in such glands. This condition must be looked upon as the result of stimulation; the cells are roused into greater activity, they proliferate more rapidly, and take up the foreign matter; the gland as a whole acting as a kind of vital sieve. In this process, however, the store of resistant energy is gradually diminished, and should tubercle bacilli find their way into the gland during or shortly after this extra stimulation, they run less risk of being destroyed by active epithelioid and lymph cells than when these cells are not already partially exhausted.

(357) *Propagation of Tuberculosis from consuming the Flesh of Tuberculous Animals.*

In the first place it is still disputed whether bovine tuberculosis is identical with human tuberculosis; if not the same,

the probability of contracting the disease would be much less than if the two diseases are identical. The balance of evidence is decidedly on the side of those who agree with Dr. Woodhead, viz., that the tubercle bacilli are identical although they may present some feeble difference of form from being cultivated in the tissues of animals, the temperature of which exceeds that of the human body, for instance the temperature of the pig and cow is from 38°·3 to 38°·8; in the calf, 39°·3; in the horse, 38°·3; and in the hen, 40°·0 to 40°·5, and it may well be that a slight rise of temperature in these animals varies considerably the powers of propagation, and also indirectly the virulence of the bacilli, as indeed Klein's experiments have shown.

M. Nocard read at the Congress on Tuberculosis a paper on the dangers to which one is exposed by the use of the flesh of tuberculous animals. It would appear to result, from his very ingenious experiments, that the muscles destroy or digest, as expressed by M. Nocard, the bacilli in such a way that the meat of animals affected with generalised tuberculosis presents but very little danger. Thus, four cats ate with impunity the flesh of a tuberculous cow, whilst a fifth cat that had eaten a lymphatic gland of the cow succumbed in a very short time to experimental tuberculosis. M. Nocard, therefore, thinks that it is not necessary to exaggerate the precautions, or to hold Koch's bacillus in great dread, adding that one can eat without fear the flesh of tuberculous animals, the tubercles of which are limited to the viscera and to the different lymphatics; even that of animals, the tuberculosis of which is generalised would be but exceptionally to be dreaded.

W. Kastner also has made a research as to whether the muscles of an animal affected with tubercle of the lung may be eaten with impunity. He made infusions of meat from animals thus affected and injected the infusions into the peritoneal cavities of guinea-pigs. Out of 16 animals thus treated 12 remained healthy. Kastner concludes that special dangers from infection are not to be feared save in the rare cases in which tubercles are to be found in the muscles.

On the other hand Professor Jeannel, of Toulouse, has studied the generalisation of tuberculosis by the inoculation of rabbits. Extirpation on the fourth day of the glands above the point inoculated did not prevent the success of the inoculation, which is

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a proof that the bacilli had not been arrested in the lymphatic system. Moreover the blood of a rabbit inoculated by subcutaneous grafting behaves like a virulent dilution from the second day, perhaps earlier. Injected *en masse* in the peritoneum, this blood determines an experimental tuberculosis. Hence M. Jeannel does not believe in local tuberculosis; for him the malady is generalised in all the organism before manifesting its existence by visceral localisation.

The question as to whether tubercle is ever localised in animals, whether it is confined to the lung, brain, kidney, or liver is one which bears directly upon the practice of a medical officer of health. If in the opinion of those best able to judge; an animal with a small portion of lung alone showing signs of disease, the rest of the viscera being healthy, and the flesh even when submitted to a strict microscopical examination showing no bacilli—yet contains invisible spores which when placed under suitable conditions may develope into tubercle; then it is the duty of the health officer to condemn the whole animal for the least speck of undoubted tuberculous taint. This is the view taken by the Congress on Tuberculosis which met at Paris in 1889, and this is the view taken by Dr. Russell, of Glasgow, as shown by the leading case of prosecution relative to diseased meat in that city fully reported in *Public Health*, Vol. II., p, 75, and also published as an official sort of blue book by the Glasgow Sanitary Authority. The question cannot be said to be entirely set at rest but the evidence certainly goes so far as to show that this drastic course is the safest, and that such meat does in fact generally contain a few of the bacilli or their spores, and that such meat when eaten in a half-cooked state by young children who inherit some weakness of tissue resistance or are at the time in a state of imperfect health may, and does, produce a certain amount of tubercular infection.

(358) *Disinfection of Tuberculous Products.*

It is in the first place important to know in what excreta the tubercle bacilli are likely to be found.

In the sputum of the phthisical, it is a matter of common knowledge and utilised daily in clinical work that myriads of the

specific micro-organisms are to be found. With regard to the urine the following researches may be mentioned : Lichtheim [1] found in the contents of the renal pelvis of a corpse, tubercle bacilli; Rosenstein [2] also succeeded, in the urine of a person suffering from tuberculosis, in recognising the tubercle bacilli, and thus confirming the diagnosis of tuberculosis of the urogenital apparatus; Babes [3] claimed priority, since he had a few days earlier communicated a similar discovery to the Anatomical Society of Paris. A number of researches followed, recording successful attempts in finding tubercle bacilli in the urine of patients suffering from tuberculosis of the genito-urinary tract. Such observations were by Smith,[4] Irsai,[5] and Probstiug [6]; Philipowiez,[7] who not only in chronic tuberculosis of the kidney, but also in acute miliary tuberculosis, found in the urine of the corpse tubercle bacilli; farther by Kerstein,[8] who found tubercle bacilli easily by allowing the urine to subside in a conical glass, and filtering off the sediment; lastly, by Morpurgo and Krecke.

The solid excreta from the tuberculous have seldom been investigated. Cramer [11] was the first who recognised in them tubercle bacilli; he also avers that he has several times found bacilli in stools of the healthy, which were not to be distinguished from tubercle bacilli. Lichtheim [12] and de Giacomo [13] found tubercle bacilli in the loose evacuations of patients suffering from tuberculosis of the intestines; and, in the non-tuberculous, large cocci and spore-like forms which gave the same colouration as tubercle bacilli. Koch and Gaffky [14] could only recognise tubercle bacilli in the dejecta of the phthisical with marked symptoms of intestinal tuberculosis; they also confirmed the other researches of Lichtheim and de Giacomi on the presence of spores, which could be coloured like tubercle bacilli. Lastly, Wolfram [15] is to be mentioned, who

[1] *The Lancet.* 1886. [2] *Central. f. d. Med. Wissenschaft.* 1883. No. 5.
[3] *Central. f. d. Med. Wissenschaft.* 1883. No. 9. [4] *The Lancet.* 1883.
[5] *Wiener med. Presse.* 1884. No. 37.
[6] *Berliner klin. Wochenschrift.* 1884. No. 37.
[7] *Wiener med. Blatter.* 1885. 22.
[8] *Anthiel d. Tuberc. a. d Aetiol. App. Dissert.* Berlin, 1885. *Deutsche med. Wochenschrift.* 1886. No. 15.
[9] *Archiv. p. l. Scienz Med.* Vol. X. No. 19.
[10] *Münchner med. Wochenschrift.* 1887. [11] *Ibid.*
[12] *Ibid.* [13] *Fortschritte der Med.* 1883. No. 5.
[14] *Mittheilungen aus dem Kaiserlich. Gesundheit.* Bd. II.
[15] *Praeglad lek.* 1884.

found tubercle bacilli in the stools of persons affected with tuberculosis of the intestines.

In purulent discharges from the ear of the phthisical, tubercle bacilli have been frequently found, *e.g.*, by Eschle,[1] Voltolini[2] (in two of his cases caries of the petrous bone was also present), Ritzefeld,[3] and Nathan[4] (in three of his cases there was also caries of the mastoid process, or of the smaller bones of the ear). Lastly, Habermann[5] was able to recognise tubercle bacilli in a number of corpses, who in life had been affected with tuberculous changes in the middle ear.

To these must be added various scrofulous discharges; Holtz[6] for instance has found tubercle bacilli in the glandular swellings of scrofulous affections, in certain kinds of eczema and subcutaneous abscesses; Volckman[7] has even found bacilli in the scrapings of the epidermis of scrofula.

There have been several exact researches as to the disinfection of tubercle, the leading one being that of Dr. Fischer,[8] who discovered the remarkable power of aniline water as a disinfectant for tuberculous sputum. If sputum be treated with ten times its bulk of aniline water and allowed to remain in contact 24 hours, it is fully disinfected, but he at the same time points out that considering the relative price of aniline water and that of carbolic acid, the latter is preferable; he found that 5 per cent. carbolic acid added in equal bulk to the sputum and acting for 25 hours fully disinfected.

Corrosive sublimate did not give so favourable a result: 1 to 500 solution added to sputum in the proportion of one part of sputum and one of the sublimate solution failed to disinfect. In all the above the result of the disinfection was ascertained by subcutaneous injection of the disinfected and undisinfected sputum into animals.

A heat of 100° when dry sometimes failed to disinfect, although it acted during 60 minutes. Boiling for 10 minutes, or a steam heat acting for 15 minutes disinfected perfectly.

Yersin[9] has made some experiments by the "thread" method

[1] *Deutsche med. Wochenschrift.* 1883. No. 30. [2] *Ibid.* No. 31.
[3] *Ueber d. Tuberc. des Ohrés. Dissert.* Bonn. 1884.
[4] *Deutsche Arch. f. klin. Med.* Bd. XXXV.
[5] *Präger med. Wochenschrift.* 1885. No. 6. *Zeit. f. Heilkunde.* Bd. VI.
[6] *Klin. Arbog.* 1885. [7] *Archiv. f. klin. Chirurgie.* Bd. XXXIII.
[8] *Mittheil. aus dem. Kaiser. Gesundheitsamte.* 1884.
[9] *Annales de l'Institut Pasteur.* No. 2, 1888. *Public Health,* vol. i. 1889.

described at page 315. This method is of course inferior to that of direct inoculation, but it has its value. He gives the following as the result of his experiments with the bacillus of tubercle :—

Substance Used.	Time.
Phenol 5 per cent.	30 secs.
,, 10 ,, ,,	1 min.
Absolute Alcohol	5 ,,
Iodoform in Ether 1 per cent.	10 ,,
Ether	10 ,,
Mercuric Chloride 1 per cent.	10 ,,
Thymol	2 hrs.
Salicylic Acid	6 ,,

He also studied the action of heat, and declares that at a temperature of above 70° sterilization is effected.

(359) *The Prevention of Tuberculosis.*

The Medical Officer of Health at present is neither aided by public opinion nor by statute in any attempt he may make to directly stop the propagation of tuberculosis. The only way open to him is to direct his attention to dampness of habitation, to overcrowding, to tuberculous meat and to diseased milch cows; in all these points he has a certain amount of power, but to isolate the affected person, to disinfect articles infected with tubercle bacilli, he has no power, unless he can get his authority to consider tuberculosis as "an infectious disease" under the 120–122 sections of the Public Health Act. This will no doubt come in time, but the knowledge that the medical and scientific world possess is distinctly in advance of the knowledge of the people at present. The people will have to be educated on this matter, and once the danger of "catching" consumption is fully recognized, there will be no difficulty in the first place of obtaining power to isolate those cases where there is likely to be danger to the healthy, and in the second place to have each case notified to the sanitary authority. From the large number of victims to tuberculosis in this country, it is a far more important malady to have notified than such purely infantile complaints as measles.

Phthisis and miliary tuberculosis should be treated in a public health sense exactly as an infectious fever, the sufferer should be isolated, the liquid and solid excreta disinfected, preferably with

10 per cent. carbolic acid and the sputum of the phthisical received on rags or paper and burned. The propagation of tuberculosis by milk is to be met by a more rigid inspection of milch cows than has heretofore been made, and when proper abbatoirs are established throughout the country a strict meat inspection will then be possible, but until that is done a very large amount of the meat consumed must be derived from tuberculous animals.

CHAPTER XXXI.

MALARIA—MALARIOUS DISEASES.

(360) *The Effects of Malaria.*

UNDER the somewhat indefinite term of malarious diseases is meant those maladies which experience has shown to be intimately connected with a particular condition of soil.

Malarious soils are all more or less marshy, or are tracts in the vicinity of marshes ; places which are well drained or dry, and those which are covered with water are not malarious. The diseases are thus intimately connected with some particular kind of vegetable decomposition.

The effects of malaria in their lightest form express themselves as neuralgias of an intermittent type, or as epidemic jaundice ; the author, for instance, has noticed that in a malarious tract from time to time occur a number of almost simultaneous cases of more or less pronounced jaundice without fever or other symptom ; but the most typical malady of all connected with malaria is that of ague or intermittent fever. In the hotter parts of the world there is also yellow fever ; this has several analogies to the intermittents.

(361) *Bacteriology of Malarious Diseases.*

Probably there are several kinds of micro-organisms which produce as many varieties of intermittent fever. Klebs and Crudeli[1] have, however, isolated from cases of intermittent fever a bacillus from 2 to 7 μ long, which is capable of growth into twisted threads. Spore formation takes place at the centre or at either end. Marchiafava[2] has also discovered in the blood of persons

[1] *Archiv. f. Experimental Pathol.* 1879. [2] *Ibid.*

suffering from intermittent fever similar bacilli with end spores. These kinds, if indeed they are not identical, have been found in the soil of the Roman Campagna. Inoculated into rabbits they produce an intermittent fever, and in the spleen and marrow the threads and spores are found in abundance. There have also been found in the blood in cases of malaria amœboid bodies and motile filaments.

The modern theory, therefore, is that these bacilli or analogous micro-organisms are produced in vast numbers in malarious soils, that the spores are raised by evaporation or by the agency of wind, that they float in the atmosphere, fall with the night dews, and are breathed into the lungs or swallowed with the food or saliva and produce the maladies enumerated.

(362) *Geographical Distribution of Malarious Tracts.*

In this country the fens of Norfolk and Lincolnshire used to be noted haunts of malaria, but the drainage of both these counties has reduced the number of cases greatly, and fatal ague is quite an insignificant cause of death in the Registrar-General's returns. It is in the deltas, the marshy banks, and the embouchures of rivers that agues are to be looked for. In Europe the Italian *maremma*,[1] the plains of Walcheren and of Rosendaal, the lines of detached pools along the Guadiano in Spain, impress their malarious character on the memory as a cause of great mortality of armies in the historical campaigns. In India the stations of Calcutta, Chinsurah, and Berhampore are highly malarious. In America malaria hangs about the Orinoco, the Amazon, and other great rivers; in short, there is scarcely a country in the temperate and torrid zones which have not portions of moist and swampy land dedicated to malaria.

(363) *Malaria from Local Causes.*

Malaria may spring from essentially local and removable causes. The Medical Officer of Health may find from careful inquiry that in a particular group of houses or in a particular house from time to

[1] A good account of the Italian *maremma* and the history of intermittent fever in Italy is given in *Lettres écrites d'Italie en* 1812 *et* 1813, *par F. Sullin de Chateauvreux.* Paris, 1816.

time cases arise which have a more or less malarious character; in such instances, the height of the ground water and the nature of the soil will have to be carefully investigated. Nor must it be lost sight of that there are cases on record which show that heaps of decaying or drying vegetable substances will cause intermittent fever; for instance, it is an accepted fact in the Netherlands, France, and Italy that the steeping of flax in stagnant water and spreading it out to dry has been followed by paludal fever. In India large masses of exhausted indigo plants put in heaps has caused intermittent fever, when in a state of putrefaction, to families to leeward of the heaps.

(364) *Prevention of Malaria.*

The preventive measures are good drainage, the removal of stagnant ponds, of decaying masses of vegetation or heaps of vegetable matter. Travellers having to pass through a malarious country may to a certain extent protect themselves from malaria by dosing with quinine; it has been repeatedly shown that provided the doses are large quinine has a real preventive quality. The doses of the sulphate should be 5 grains at first twice a day, and then gradually increased up to any dose which can be borne without singing in the ears or other symptoms of "quinism."

CHAPTER XXXII.

MICRO-PARASITIC MALADIES PRIMARILY ATTACKING THE INTESTINE.

ENTERIC OR TYPHOID FEVER.

ENTERIC or typhoid fever is a malady produced by a micro-organism which attacks the intestine in the first place, and afterwards other organs; it is attended with fever, and mostly diarrhœa, and other systems of constitutional disturbance.

(365) *Statistics of Mortality from Enteric Fever.*

The average deaths from enteric fever in England during the eighteen years from 1869 to 1886 inclusive reaches the mean number of 7,203, the extreme yearly numbers being 5,061 and 8,913; the mortality per million from typhoid fever is given for the same number of years in rates varying from a minimum of 173 to a maximum of 371.

Typhoid fever is especially a disease of the young adult, and is more prevalent in country places than in well-drained towns. Diffused generally throughout the civilized world it is particularly prevalent in warm climates such as India. It is the most fatal of all the diseases to which the British soldier in India is liable, and it occurs in all parts of India from the Eastern to the Western frontiers; on the hills and mountains as on the plains there is no station and cantonment which is exempt.[1] This great prevalence in India is more due to sanitary than to climatic conditions.

[1] *Twenty-fourth Annual Rep. San. Com. India.* 1887.

During the eight years ending 1887, the following are the admission and death-rates of the army in the three Presidencies.

	Admissions of Typhoid cases to Hospital per 1,000 strength.	Death-rate per 1,000 strength from Typhoid.
Bengal	11·5	3·53
Madras	7·1	2·17
Bombay	8·0	3·02

(366) *Case-Mortality of Enteric Fever.*

The case-mortality of enteric fever in England is somewhat less now than formerly; during the three years 1886-8 the case-mortality of the hospitals of the Asylum Board varied from 14·59 to 14·85 per cent. Murchison's statistics derived from the London Fever Hospital, 1848-1859, give an average of 17·2 per cent., and the average mortality of 28,051 cases treated at various hospitals at home and abroad in various years up to 1870 is given as 17·45 per cent.

The liability to attack is influenced enormously by age, but the death-rate is not influenced in anything like the same proportion—in which it contrasts with typhus, for instance Murchison gives the following figures derived from London fever hospital experience:—

	Typhus Mortality per cent. of the cases.	Enteric Mortality per cent. of the cases.
Under 10 years	1·65	11·36
,, ,, ,,	3·27	... ...
From 10 to 14	1·65	12·86
,, 15 to 19	3·96	15·48
,, 20 to 29	12·34	20·46
,, 30 to 39	22·63	25·90
,, 40 to 49	35·97	25·00
Above 50	57·03	34·94

From whence it appears that the death-rate increases with advancing age to much less extent than typhus.

(367) *Incubation Period.*

If the modern view is correct, viz., that typhoid depends upon the invasion of the intestine by a micro-organism, there ought not to be a very definite incubation period. For in experiments with anthrax (a micro-organism of something the same nature), in which the bacillus anthracis has been introduced into the system

of animals by dosing the natural food passages, the incubation period has been variable. For instance Koch, Gaffky and Loeffler [1] fed sheep, some with large doses of anthrax, others with small, the feeding being done in such a manner as to avoid all wounding of the mouth. In the first case in which sheep were fed with large doses, they died without exception in a few days from anthrax infection; on the other hand, out of ten sheep who daily took a small dose of anthrax, those that were affected at all died respectively the 5th, 6th, 11th and 19th day after the beginning of the feeding. In all the mortal cases a post-mortem examination made it clear that the anthrax had infected the intestine, the seat of infection being as in typhoid the lymph follicles and Peyer's patches.

After these experiments it will cause no surprise to find cases like those cited by Murchison in which it appears clear the incubative period was only two days. In most of the cases recorded the incubation period has been about two weeks, but it may be much shorter and it may be longer.

(368) *Seasonal Prevalence.*

Enteric fever is markedly influenced by season, by far the greater number of cases in Europe and America occurring in the autumn, hence one of its synonyms "autumnal fever"; the least number of cases occur in April and May.

5,988 cases admitted into the London Fever Hospitals during the twenty-three years from 1848 to 1870 were distributed throughout the months of the years as follows:—

	Cases.	Per cent.
January	433	7·2
February	306	4·9
March	318	5·3
April	209	3·5
May	232	3·9
June	335	5·6
July	434	7·2
August	721	12·0
September	803	13·4
October	839	14·0
November	819	13·7
December	539	9·0

[1] *Mittheilungen aus dem Kaiserlichen Gesundheitsamte.* Berlin, 1884.

The experience of the Metropolitan Asylums Board is very similar (see Chart opposite). In the fifteen years ending December, 1888, the maximum occurred eleven times in October, three times in November, once in December, once in January; in 1880 the cases were few, and it was equally prevalent in August, September, and October, there being no marked difference in each of the three months, the curve being here continued, or to speak more accurately interrupted, by a straight line.

Buchan and Mitchell's curve [1] of the mortality mapped out by Bloxam's method for the deaths in London during the thirty years, 1845—74, places the maximum in the last week of October, which would well coincide with hospital experience. They point out its great similarity with the scarlatina mortality curve, differing from it though in the duration and phases of the minimum period. "Scarlatina falls below its average in the beginning of January, typhoid fever not until the last week of February; scarlet fever has its absolute minimum period from the middle of March to the middle of May, typhoid fever from the middle of May to the end of June; scarlet fever begins steadily to rise in the second week of May, typhoid not until the beginning of July, when the heat of summer has fairly set in."

(369) *Bacteriology of Enteric Fever.*

Recklinghausen [2] in 1871 found in a case of abscess of the kidney which had complicated typhoid, colonies of micrococci; he did not consider these a factor in the production of typhoid, but an accidental complication. In the following year Eberth [3] also found micro-organisms in the corpses of typhoid cases.

In 1875 Klein [4] found in a case of fatal typhoid, in the mucous membrane of the intestine, a fungus with copious mycelium and numerous macro and micro-gonidia; in a later communication Klein recognised micro-organisms in the spleen and noted the presence of micrococci in the mucous membrane of the intestine and the lymph follicles. Browicz, in 1875, discovered in the kidneys, the spleen, the muscular structure of the heart, and in the

[1] *Op. cit.*
[2] *Verhandlung der physicalisch-medicin Gesellschaft in Wurzburg*, 1871.
[3] *Zur Kenntniss der bacteritischen Mykosen.* Leipzig, 1872.
[4] *Reports Medical Officer L. G. Board.* 1875

intestine of a patient who had died of typhoid, bacilli. Socoloff,[1] in 1876, investigated the spleens of nine cases of typhoid and found micrococci in three of them. Fischel,[2] in twenty-nine cases, found micrococci in the spleen, in the remainder he could discover no micro-organism.

In 1880 Eberth made a noteworthy research. He very carefully investigated twenty-three cases of typhoid, paying special attention to the spleen and the lymph glands. The sections he cleared up with concentrated acetic acid. Out of the twenty-three cases twelve presented organisms; in each of the twelve these were found in the lymph glands, in six cases they were in the spleen. The colonies looked at first like heaps of cocci, but where they were less crowded could be seen to consist of bacilli. The rods were short with gently rounded ends; they had a soft outline and contained frequently very small, highly refractive, spore-like bodies. They were not easily stained with colouring agents. In 1881 Eberth[3] returned with new experience to the subject, and by that date had altogether investigated forty cases of typhoid. Out of these he had found the above described bacillus eighteen times; in twenty-two the result was negative. Klebs[4] published a few months after Eberth's first paper an account of a bacillus which he and his assistants had found in typhoid cases. Klebs devoted much time to the study of this bacillus and described it at length; he considered it a constant micro-organism in cases of typhoid. It is a matter of doubt whether Eberth's bacillus is the same as that of Klebs. Koch,[5] it appears, independent of Eberth and Klebs, and about or before the same time, had discovered a special bacillus in typhoid, which did not agree with any other known micro-organism.

Other researches followed, such as those of Meyer,[6] Coats,[7] and Crooke, these generally confirmed Eberth.[8]

The last noteworthy research is that of Gaffky.[9] Gaffky made a most painstaking research on the bodies of twenty-eight patients

[1] *Virch Archiv.* Bd. 66. 1876.

[2] *Präger med. Wochenschrift.* 1878.

[3] *Virch Archiv.* Bd. 83. 1881.

[4] *Arch. f. exper. Pathol. u. Pharmak.* Bd. 12, Heft 2 u. 3.

[5] *Mittheilungen aus dem Kaiserl. Gesundheitsamte.* Berlin, 1884.

[6] *Untersuchungen über den Bacillus des Abdominaltyphus. Inaug.-Diss.* Berlin, 1881.

[7] *B. Med. Journal.* 1882.

[8] *B. Med. Journal.* 1882.

[9] *Mittheilungen aus dem Kaiserl. Gesundheitsamte.* Berlin, 1884.

who had died of typhoid; he hardened the internal organs in alcohol, then cut hundreds of fine sections, these sections were treated as follows. They remained for from twenty to twenty-four hours in a methylene blue solution, made by adding a saturated alcoholic solution of methylene blue to distilled water until a very deeply coloured, non-transparent staining liquid was obtained, this was prepared fresh each time. The sections were next washed with water, dehydrated by absolute alcohol, cleared up by turpentine, and mounted in Canada balsam. Of the twenty-eight cases in one alone he failed to find Eberth's bacillus; this might be explained from the fact that the death took place at the end of the fourth week from peritonitis arising from a perforation. In twenty-two instances the colonies were found in the spleen; in thirteen cases in which the liver was examined, colonies were found in them all; in seven cases in which special attention was turned to the kidney, in three the bacilli were found; in four cases in which the mesenteric glands were investigated, in three the bacilli were found. Probably the failure to find the bacilli in other cases by other observers arises from the technical difficulty of the research, and also because the colonies are scattered in some cases at wide intervals; in such it is only by making a number of sections that success will be attained. In one of the twenty-eight cases Gaffky found micrococci, he follows Recklinghausen, Eberth, Koch, and others in considering their presence as secondary and not an essential of the disease. Gaffky was able to cultivate the colonies by the following process:—The spleen from the corpse of a typhoid patient, showing no trace of decomposition, was washed carefully with a one per thousand solution of corrosive sublimate, and then by means of a knife previously held in the flame to effectually sterilise it, cut into two halves.

Other slices were made by freshly sterilised knives, and platinum wires, which had been the moment before made red-hot so as to destroy any kind of organism infected from these surfaces. The platinum wires were then drawn over nutrient gelatin so as to make a streak. The cultivation of this miniature-sown furrow took place in a moist glass chamber at the ordinary temperature of the room. After twenty-four hours the streak showed a white cloudiness which, after another twenty-four hours, had increased in intensity, but was still confined to the streak. The gelatin did

not become fluid. On examining with a low power the streak was found to consist of a large number of roundish, granular colonies of a light brown colour. On now taking minute portions from the streak and examining the colony thus removed in a drop of distilled water and highly magnifying the bacilli were found to be motile.

Pursuing his researches, Gaffky found that the bacillus grew in quite a characteristic way on slices of potato; the potato was prepared in the way familiar to bacteriologists and the surface "seeded" with the bacillus. The slices were cultivated in the moist glass chamber at the ordinary room temperature. In forty-eight hours, if a particle of the surface be taken for microscopical examination, it seems as though the whole surface is covered with a connected resistant skin, and from whatever part a tiny sample is taken it is found to consist of incredible numbers of the motile bacillus; these are most of them of the ordinary size, but others are in the form of long glittering threads. There is no other bacillus known that is motile, does not liquefy the gelatin, and which grows on gelatin in the way described. The motile property is due as usual to motile threads at the ends of the rods. At the ordinary temperature of rooms no spore formation takes place, but it was found that spores could easily be produced by cultivating at from 30° to 40°. The spores are as usual long lived and resistant. Fig. 52 (*a*), represents the appearance of a stab culture in gelatin of the bacillus. Fig. 52 (*b*), is probably the same bacillus found by Klein in a fatal case of diarrhœa.[1] Gaffky failed to raise the same bacillus from typhoid stools, because other organisms liquefied the gelatin. Chantemesse and Widal[2] have been more successful. They found that trichloride of iodine added to gelatin in the proportion of 1 to 500 prevented the growth of all ordinary micro-organisms, but the typhoid bacillus was an exception. Using this medicated nutrient gelatin, the authors affirm that they have separated Eberth's bacillus from typhoid excretions. Gaffky was similarly unsuccessful in attempting to raise the bacillus from blood.

Recently there have been published improved methods; M. Rodet[3]

[1] *Supplement, Seventeenth Annual Report, Local Government Board.*
[2] *Gaz. hebd. et de Med. Chir.* 1887. No. 9, 146.
[3] *Comptes rendus de la Société de Biologie,* T. ii., No. 8. *Public Health,* ii., 382.

has taken advantage of the fact that most micro-organisms will not grow at a high temperature, *e.g.* 44·5° C., but this temperature is not destructive of the typhoid bacillus. M. H. Vincent [1] modifies this process by sterilizing broth, and to every 2 c.c. adding a drop of carbolic acid and then testing, say drinking water, by

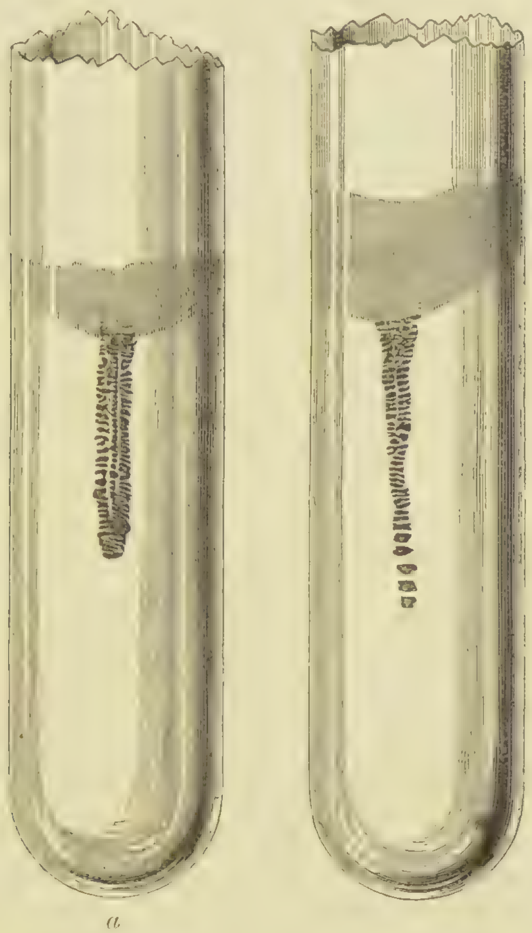


FIG. 52.

adding from five to fifteen drops to the broth. On now cultivating at 42° if the broth remains clear for twelve hours, the typhoid bacillus is not present; on the other hand, if it clouds, the turbidity is probably due to the bacillus, and by successive removes, that is, by taking minute quantities of the already clouded broth and transplanting into a fresh tube, and so on, an

[1] *Comptes rendus de la Société de Biologie*, T. ii., No. 5. *Public Health*, ii., 381.

absolutely pure cultivation may be obtained and the characters of the suspected microbe studied. Rodet and Roux[1] believe that there is an intimate relation between the bacillus *coli communis* and the bacillus of typhoid fever, the latter being indeed the bacilli in a state of attenuation or degeneration.

Eberth's bacillus has rather frequently been found in water which has produced typhoid. Beumer, for instance, found it at Greifswald, Rodet at Sous-Ville-Charmoux, Arloing at Cluny, Widal at Paris, and Chantemesse at Clermont-Ferrand and Pierrefonds. In the latter case Chantemesse found no less than 25,000 bacilli to the litre in a well—the water of which apparently communicated typhoid fever to twenty persons—chemical analysis in this case indicated no great pollution. To these examples may be added several in the United States. Dr. Prudden,[2] of New York, found Eberth's bacillus in a filter in a household, some of the members of which suffered from typhoid, and filters from affected houses during the same outbreak were examined by Dr. Ernest of Boston and by Dr. Swartz, in a few cases with a positive result.

Numerous experiments by Klein, Murchison, Birch-Hirschfeld, Klebs, Gaffky, and many others, have been made as to the possibility of infecting animals with true typhoid. For this purpose monkeys, guinea-pigs and various other animals have been fed with typhoid stools or artificial cultivations of Eberth's bacillus, products have been also injected subcutaneously or into the veins. Birch-Hirschfeld appears to have given a rabbit some disease similar to typhoid by feeding it for a long time with food infected with typhoid excreta. But considered as a whole the experiments are not altogether conclusive.[3]

(370) *Symptoms.*

In a few cases which are specially dangerous to the public the only deviation from health is an almost painless looseness of the

[1] *Comptes rendus de la Société de Biologie*, T. ii., No. 7.

[2] *Fourth Annual Report of the State of Maine.*

[3] It is stated that Vaughan has inoculated successfully dogs and cats with Eberth's bacillus found in the Iron Mountain drinking water.—*Sixteenth Report of the Michigan Board of Health.*

bowels, with a little fever at night, a general loss of appetite and slight weakness. Such cases often from first to last go about their ordinary avocations, seek no medical advice, and must be infective centres, without doubt doing occasionally much damage. The author has seen three of these cases in which one had suffered for at least a fortnight, in the second some nine days, and in the other a long time which could not be definitely fixed, but was probably seventeen or eighteen days. The ordinary typical mild case presents the following symptoms:—The commencement is insidious, it may be marked by diarrhœa or by rigors, fever of a remittent character sets in, the temperature rising the first evening to 100° to go down half a degree or more the following morning. The second evening the temperature will be higher, say 101°, rising as a rule each night up to the fifth or sixth day when it will attain 105° or 106°, keeping for a week or more at or about this evening temperature, and going down each morning a degree or a degree and a half. About the twelfth or thirteenth day comes a change. The temperature, although nearly as high as before in the evening, becomes much less in the morning, going down three or four degrees at the end of the third week, sometimes before; the fever markedly declines and the morning temperature becomes nearly normal, and in the fourth week convalescence sets in. The tongue during this time is mostly red and fissured or becomes dry and brownish. The abdomen is tender, there is gurgling in the iliac fossa upon pressure, the spleen on careful percussion is found to be larger than natural. Between the seventh and fourteenth days there are successive crops of isolated elevated rose-coloured spots, each spot lasts about two or three days. There is nearly always diarrhœa, in a few cases hæmorrhage from the bowels. In many cases bleeding from the nose. Prostration comes on rather late, patients keeping up to the seventh or tenth days. The termination of the disease in mild cases may be as early as the twenty-fourth day, in severe it is protracted to the thirtieth or longer. Sometimes even a mild case is carried off by perforation of the intestine or by profuse hæmorrhage. The prognosis on this account must always be guarded; with typhoid until complete convalescence no one can tell what will happen even when all fever has passed, in a few instances relapses take place. Coma is occasionally present and sometimes active delirium.

K K 2

(371) *Predisposition.*

With the exception of a previous attack of typhoid, which to some extent renders a person not liable to contract the same disease a second time, there is only one marked difference in individual susceptibility, and this one depends on age. The disease is almost entirely confined to children and adolescence, a point to be borne in mind in the selection of nurses for typhoid cases. "The mean age of 1,772 cases admitted into the London Fever Hospital during ten years, 1848-57 was 21·25; that for males being 21·45, and for females 21·06. These averages are more than five years under those of the entire population" (Murchison). Persons under thirty are more than four times as liable to enteric fever than persons over thirty. This is remarkably different to typhus. At one time it was thought that owing to anatomical reasons it was not possible for the aged to develop typhoid, but the cases of people over fifty, and even a few over seventy, which have been proved by *post-mortem* examination to have suffered from fatal typhoid are sufficient in number to disprove this view. All that can be said is that the liability to contract typhoid after thirty years of age, progressively diminishes, and that cases over fifty are rare.

(372) *Pathological Appearances after Death.*

In the works of Louis,[1] Chomel,[2] Rokitansky,[3] Jenner,[4] Hoffman, Murchison [5] and W. Budd [6] will be found the most minute details of the anatomical lesions observed in cases of death from typhoid fever. These storehouses of information contain a vast amount of minute details as to the appearances of every organ and tissue. The morbid changes however which are *always present* in this disease and *never present* in any other are mainly in the intestines. As Dr. Budd truly remarked in his classical monograph, "Take the diseased intestine away and it becomes impossible, in a common out-

[1] Louis, *Recherches sur la Fièvre Typhoid.* 1841.
[2] Chomel, *Leçons de Clinique Méd.* Tom. I. Paris, 1834.
[3] Rokitansky, *Path. Anatomie.*
[4] W. Jenner, *Med. Chir. Transact.* Vol. xxxiii. Ed. *Monthly Journal of Med Science*, 1849-50.
[5] *The Continued Fevers of Great Britain.*
[6] *Typhoid Fever*, by W. Budd, M.D., F.R.S. London, 1873.

PLATE V

ward survey, at least, to distinguish the body of a man dead of typhoid fever from that of a man killed by many another septic poison ; take away the body but leave the intestine, by the marks upon it death from this fever is at once distinguished from death from every other cause." The greatest interest is in those cases which have died at a sufficiently early stage to show the commencement of the process. Death so rarely takes place before the end of the second or third week of the fever that there have been comparatively few opportunities of investigating this stage. An exquisite example is however figured in Dr. Budd's work of the appearance of the intestine probable before the seventh day (see Plate V., Fig. 1, which has been produced from the original drawing) ; in this the ileum presents its mucous membrane covered with raised roundish bodies so strikingly like an eruption, that Dr. Budd considered it analogous to an internal exanthem. More particularly in the earliest stage which has been witnessed a certain number of Peyer's patches, or of the isolated follicles, as the case may be, acquire a considerable increase of thickness, and stand out in relief on the internal surface of the gut. Chomel says that the intestine feels as if a solid and elastic substance had been inserted between the coats. On cutting through a patch thus affected a cheesy yellow substance exudes. The mucous membrane at this stage may be perfectly healthy, exhibiting no traces of ulceration. In a case in which Meyer[1] had an opportunity of observing the *post-mortem* appearances on the second day of the illness there was found simply swelling of the solitary follicles and Peyer's patches, without the slightest sign of ulceration ; the mesenteric glands were not swollen. In this perfectly recent case a microscopical examination revealed an extraordinary number of Eberth's bacillus in the cells in the submucosa and between the muscular layers or coats of the intestine. The second stage is that of ulceration. This commences in two ways; to the one the French observers have given the name of *plaques molles*, to the other *plaques dures*. In the first the mucous membrane becomes softened, and one or more superficial abrasions appear on the surface of the diseased patch, extending and uniting to one large ulcer which proceeds at various depths through the bowel coats and may go on to perforation. In the case of the more common *plaques dures* the mucous membrane and sub-mucous

[1] *Mittheilungen aus dem Kaiserlichen Gesundheitsamte.*

tissue become detached in the form of a slough, leaving behind an ulcer. See for example Plate IV. (*a*), which has been drawn from a preparation in the Museum of the Royal College of Surgeons (No. in Catalogue, 2499). It is a portion of the ileum injected and everted. The large ulcer occupies the site of one of Peyer's patches. There are also several smaller circular ulcers formed by ulceration of the solitary glands. The time of the ulceration is so variable that no inference as to the age of the disease can be drawn from its presence. Ulcers have been met with as early as the second day, Louis, Hoffman, Murchison, Chomel, each record a case in which ulceration had not commenced on the twelfth day, in the majority of cases however ulceration will be found after the tenth day. The next stage is the separation of the sloughs and the cicatrization, a kind of interim period within which death often takes place. Seen at this stage Murchison gives the following characteristic marks by which the ulcers are to be distinguished from other ulcers.

(1) They have their seat in the lower third of the small intestine, and their number and size increase towards the ileocæcal valve.

(2) They vary in diameter from a line to an inch and a half. Close to the cæcum a number of ulcers often unite to form a mass of ulceration several inches in extent.

(3) Their form is elliptical, circular, or irregular; they are elliptical when they correspond to an entire Peyer's patch; circular when they correspond to a solitary gland; and irregular when they correspond to a portion of a Peyer's patch, or when several unite to form one.

(4) The elliptical ulcers are always opposite to the attachment of the mesentery. They do not form a zone encircling the gut (as may be observed in the tubercular ulcer), but their long diameter corresponds to its longitudinal axis. An elongated ulcer, however, running transversely may result from the confluence of several ulcers originating in the solitary glands, especially in the larger bowel. See Plate V., Fig. 2, and Plate IV. (*a*).

(5) Their margin is formed by a well-defined fringe of mucous membrane detached from the submucous tissue, a line or more in width and of a purple or slaty blue colour: this is best seen when the bowel is floated in water. After the separation of

the sloughs, there is no thickening or induration of the edge as in the tubercular ulcer.

(6) Their base is formed by a layer of submucous tissue, by the muscular coat or by the peritoneum. There is no deposit of morbid tissue at the base of the ulcer, although sometimes fragments of the yellow sloughs may be seen adhering both to the base and edges.

The last stage is cicatrization. Usually in the fourth week the ulcers nearest the cæcum commence to cicatrize and the rest gradually follow, but they may become chronic, and then the convalescence is much delayed. The cicatrices are slightly depressed, less vascular, smoother, and the intestine is at that spot thinner than elsewhere. According to Chomel all traces of the ulcer in a short time disappear. The mesenteric glands are always enlarged, save perhaps at the very first commencement of the disease as in Meyer's case, and they become infiltrated with the same yellow matter as the glands of the bowels, the spleen is invariably enlarged, the liver and kidneys occasionally hyperæmic.

(373) *Diagnosis of Typhoid.*

There may be difficulty in the diagnosis of typhoid during life, there can be none after death; the essential anatomical signs in the intestines, aided by a bacteriological examination of the spleen will in all cases give reliable results. It should also be noted that Gaffky found that in a case where he failed to demonstrate in the spleen micro-organisms, yet the bacillus could be raised by cultivating small portions of the tissue.

During life typhoid has been confounded with typhus, remittent fever, pyæmia, influenza and various forms of tuberculosis, all of which occasionally closely simulate typhoid fever, besides which trichinosis has been mistaken for typhoid. Cases of the above have puzzled physicians of great experience, but as a rule, provided accurate thermometric observations are taken for a few days and the patient closely watched, the diagnosis of typhoid presents no difficulty.

(374) *Theory of the Propagation of the Disease.*

The modern theory is that the specific microbe, which according to Koch, Eberth, and Gaffky, is a bacillus, forms within the body,

spores, and these spore-holding bacilli are expelled in myriads with the stools; like all spore-bearing micro-organisms they are very resistant, and may be preserved for an unknown long period. The stools infect drains, cesspits, sewers, or the soil itself; if the excretal matter obtain access to food of any kind there is a liability to infect those taking such food; water of course may also be infected either directly or indirectly from the spring passing through already polluted earth. There can be no typhoid without the bacillus, but on the other hand we have no evidence to prove that the spore-holding bacillus *must* have passed through the intestine of a man before it infects a second; on the contrary, there is every probability that it has something of the same history as the bacillus anthracis, and that it can under appropriate conditions thrive as easily as it does in the incubator of the bacteriologist.

Enteric fever has many a time attacked the traveller in tracts of country in the tropics which are not known to be inhabited, and in numbers of cases in this country the most exhaustive inquiry has failed to show traces of a pre-existent case. Typhoid fever does not arise *de novo*, for no cunning concoction of filth aided by warmth and moisture will create an Eberth's bacillus, the bacillus has sprung from some pre-existent colony, that colony from a previous one, and so on: but to say that an infective colony must have descended from micro-organisms flourishing in a human body is going beyond existing evidence, the balance of which points in the other direction. The most reasonable theory is that the cause of typhoid is a vegetable parasite capable of having an independent existence and propagating its kind, and completing its cycle of existence quite independent of the body; probably its normal existence is that of a saprophyte. Hence its endemic prevalence in certain parts, hence the impossibility of always tracing typhoid from one person to another, and hence the mysterious isolated outbreaks which from time to time occur.

(375) *The Ground Water Theory.*

Pettenkofer has laid great stress on the connection with the height of the ground water and the prevalence of typhoid. It is true that when typhoid most prevails the ground water is sinking or at its lowest, and when typhoid least prevails the ground water

is rising or at its highest, but this may possibly be explained by the fact that in the one case the springs are more dilute and contain in a given bulk the least impurity, so that presuming a specific infection when the ground water is highest the infective colonies will be farther apart than in autumn, when the springs are low and any impurity concentrated. Whatever the explanation the fact remains, which whether essential or merely coincident, is too constant for the student to neglect.

(376) *Propagation of Typhoid.*

Occasionally typhoid excreta may be dried and blown about in dust, become breathed, and thus getting access to the mouth, be swallowed with the saliva; while admitting this as possible, there is no instance on record, in which this mode of transmission has been rendered more probable than other ways. The whole pathology of the malady points to the cause gaining access to the alimentary canal by drink or food. It is undoubtedly in some way or other swallowed, the chief agent being water. That water specifically polluted with typhoid excreta is liable to produce typhoid, is so well established by a mass of evidence that only a few examples need be cited.

The outbreak of typhoid described by Dr. W. Budd,[1] in 1847, may be referred to, at Richmond Terrace, Clifton, in which the inhabitants of thirteen contiguous houses drinking a common polluted water supply were nearly all struck down at the same time with typhoid. Other families in the terrace under precisely the same conditions, but not drinking this particular water, escaped. There is again the particularly instructive outbreak detailed by Mr. Spear,[2] in the Mountain Ash district, in which a portion of the water mains were found to be carried through an excessively foul sewage deposit, and the main being leaky, at times actually drew sewage matter into the pipes. The typhoid area in Mountain Ash strikingly coincided with the distribution of water by the particular branches supplied by this portion of the main, whereas the other portions of the village supplied with

[1] *Op. cit.*
[2] *Public Health*, vol. i. p. 183; *L. G. B. Med. Off. Rep.* 1887.

the same water, but unpolluted, escaped.[1] There is also the remarkable outbreak detailed by Gaffky,[2] which will always hold a place in the literature of this disease, on account of the great minuteness and thoroughness with which the epidemic was investigated. The outbreak occurred in the summer of 1882 in the garrison at Wittenberg. It was practically confined to those who drank from a particular well, which well was polluted by a neighbouring cesspool. Into this cesspool in March and also in May the dejections of two isolated and successive cases of typhoid for several days had been cast; there followed in June and July no less than ninety cases. The interesting part of the history is that others drinking a spring not very far away, but considerably polluted, although not by this particular cesspit, did not suffer from typhoid. Gaffky was able to disprove infection carried by the atmosphere, or by the food, the specifically polluted water could alone be inculpated. Such cases as the foregoing, and they might be multiplied by some hundreds, are in the light of exact experiment, two neighbouring communities taking exactly the same food, the same milk supply, and breathing the same atmosphere, but differing in this one thing, that the one drink a specifically polluted water-supply, the other a water-supply which may be pure or impure, but is not specifically polluted; the one "the control," do not suffer from typhoid, the others are attacked.

Among epidemics of enteric fever which are particularly instructive is the one at Bangor in 1882, which was investigated by Dr. Barry.[3] The epidemic caused 548 cases of sickness, and 42 deaths. There was strong circumstantial evidence that the public water supply had on a particular occasion become polluted by river water flowing over the filter beds and carrying with it the accumulated dirt from the filtering surface, and also excrements which had been discharged into the river; some of these there was reason for believing were discharges from certain enteric fever cases. As another instance of the propagation of enteric fever by a public water supply, reference may be made to the Hitchin outbreak in 1883, which was investigated by Mr. H. Power.[4] Here the water

[1] Precisely the same kind of infection occurred recently in Alma Square, St. Marylebone. The epidemic is described by the author in the *St. Marylebone Sanitary Chronicles*, February, 1890.

[2] *Mittheilungen aus dem Kaiserlichen Gesundheitsamte.* Berlin, 1884.

[3] *L. G. B. Med. Off. Rep. for* 1882.

[4] *Ibid.* 1883.

was contaminated in various ways, but especially from an overflow pipe at the water works which permitted the occasional reflux of the water of the much polluted river Hiz into the tank.[1]

There are also instances in which the infection has been conveyed by milk, and in a few of these it has been demonstrated that the cans have been washed or the milk adulterated with polluted water.

(377) *Prevention of Typhoid.*

The doctrine is now firmly established that the infection is alone carried in the discharges from the bowels, hence there is no danger whatever in nursing cases of typhoid, nor in treating them at home, always *provided that the nursing is skilled and efficient,* and this cardinal fact is borne in mind. The motions themselves should always be passed into a strong disinfectant; and remembering that the typhoid bacillus on expulsion from the body is in the spore state, it is doubtful whether the sulphate of iron recommended by Dr. W. Budd is sufficiently trustworthy, for after all, ferrous sulphate is not a disinfectant of the highest rank, and it is preferable to use a 2 per cent. solution of corrosive sublimate, dissolved by means of ammonium chloride in water; this should always be placed in the bed-pan or receptacle, nor is it wise to cast immediately the discharges thus disinfected into drains, cesspits or sewers. All disinfection requires time, and at least two hours should elapse before the dejecta are thrown away. A supply of the usual weak corrosive sublimate solution 1 per 1,000 should be kept for the nurses to wash their hands in, if soiled; it is specially necessary that the hands before meals should be washed in this solution. It would naturally be far more efficacious to burn all excreta by receiving it in sawdust and cremating it in a special furnace, but this can only be done in hospitals or where special facilities are at hand. All bed-linen and bedding soiled by discharges should be thoroughly disinfected; the linen may be boiled,

[1] The student may also peruse with profit the following Reports:—Report by Mr. Power on an Outbreak of Fever at Norwood, *L. G. B. Med. Off. Rep.* for 1882; Report by Dr. Blaxall on Enteric Fever at Sherborne, *ibid.*; Report by Dr. Airy on an Outbreak of Fever at Melton Mowbray, *L. G. B. Med. Off. Rep. for* 1881; Report by Dr. Page on Enteric Fever at Beverley, *L. G. B. Med. Off. Rep. for* 1884; Report by Mr. Shirley Murphy on the Outbreak of Enteric Fever at St. Albans. (In this case there was good evidence of specific contamination of the milk supply.) *L. G. B. Med. Off. Rep. for* 1884.

the bedding should go to the hot air or steam apparatus, and be exposed at least four hours to a heat of 115° to 120° F.

In country villages, where typhoid breaks out again and again every autumn, and no special sanitary defect is discovered, the whole area of the soil is probably infected, and the only way to deal with such places in the absence of obvious causes is, I believe, to close existing water supplies, no matter how pure they may seem to be, and to change them altogether, if this can be done. How far in these cases the application round each household of a powerful disinfectant to the soil itself, as well as to the drains may be of service has yet to be proved. A constant series of cases occurring regularly in the autumn among children, would point to the probability of the soil itself being infected, for as is well known children sit about on the ground, continually have earth-soiled hands, and in this way contaminate their food. In any case the presence or absence of typhoid in rural communities is an excellent test of sanitation. If present, it is the duty of the Medical Officer of Health to study very closely the water supply, the sewerage disposal, and the earth contamination of the area, and to remedy any defects which he may discover.

ASIATIC CHOLERA.

(378) *History of Cholera in England.*

The first description of cholera is generally held to have been given by Garcia del Huerto, a physician of Goa, about 1560. As a disease attacking a number of people, and when introduced into a community rapidly spreading, it is without doubt a modern disease. Had it prevailed in ancient times, there would certainly have been a record of its ravages. The date at which it appeared in India is put at 1777, but at this time it was not generally diffused. In 1817, cholera was more or less prevalent through the whole of India, and from this date India may be considered the home of cholera, and from this date onwards India has exported its cholera infection at irregular intervals to Europe.

The history of cholera is complicated and confusing, and its literature voluminous; in this work written for English readers, it will be best to confine the attention entirely to our own island.

Cholera has visited England four times, the dates being 1831, 1849, 1854, 1866. In 1831 it first appeared in October; at that time there was no registration of the causes of death, but the deaths of 52,547 persons from cholera were reported through various channels to the Board of Health. The important practical observation was made that cholera was usually preceded by preliminary diarrhœa; and house to house visitation with the early administration of medicine, seemed to arrest the farther development of the disease in not a few instances.

(379) *Epidemic of* 1848-9.

In the 1848-9 epidemic, the disease was studied by a number of observers well qualified to trace out cause and effect. This epidemic taught us to look closely on the *water* and the *soil* as the chief factors that had to do with diffusion. For instance, in London, the districts supplied with water taken from the Thames above Battersea, had a mortality of 15 per 1,000; districts supplied with water from the New River, the Lea, and the Ravensbourne, 48 per 1,000; districts supplied with Thames water taken below Battersea Bridge (between Battersea and Waterloo Bridge), 123 per 1,000; in other words, the populations drinking different portions of the same river, suffered from cholera in proportion to its pollution, for it is scarcely necessary to observe that the water of the Thames above Battersea was much purer than below Battersea. Another discovery made in the 1849 epidemic with regard to London was the relationship of cholera mortality to elevation. Dr. Farre, writing his report of the epidemic said, " The elevation of the soil in London has a more constant relation with the mortality from cholera than any known element. The mortality of the nineteen highest districts was at the rate of 33 per 10,000, and of the nineteen lowest districts 100 in 10,000. The elevation in the two groups above the high-water mark of the Thames was as 71 to 10 feet (7·1). While the mortality was as 1·3 or in the inverse ratio . . . Cholera was excessively fatal in all the four districts which lie on a level with or below the Trinity high-water mark; it destroyed 144, 164, and 505 in 10,000 inhabitants. Notwithstanding the disturbance produced by the operation of other causes, the mortality from cholera in London bore a certain constant relation to the elevation of the

soil, as is evident when the districts are arranged in the order of their altitude. We place the districts together which are not on an average 20 feet above the Thames, and find on these bottoms of the London basin the mortality was at the average rate of 102 per 10,000; in the 2nd group at 20 and under 40 feet elevation, or on the second terrace, the mortality from cholera was at the rate of 65 in 10,000; in the 3rd group, or on the third terrace, 40-30 feet high, the mortality from cholera was at the rate of 34 in 10,000; in the 4th group 60-80 feet high, the mortality from cholera was at the rate of 27 per 10,000; in the 5th group 80 to 100 feet high, the mortality was at the rate of 22 per 10,000; in a district 100 feet high, the mortality was 17 per 10,000; in Hampstead, about 350 feet high, it was 7 in 10,000."

The system of registration had been in force since 1837, hence for the first time an accurate computation of the mortality was made. According to the official returns 53,293 died of cholera and 18,887 of diarrhœa.

(380) *Epidemic of* 1854.

In 1854, Sir Benjamin Hall was President of the Board of Health; he obtained the assistance of a medical council, aided by others well versed in chemistry and microscopy. This medical council or "scientific committee," studied more particularly and closely the distribution of cholera in the metropolis, and the result of their inquiries was summarised and expounded in a masterly report by Mr. Simon. "As often," said Simon, "as Asiatic cholera had been epidemic in London, it had been observed to prevail with especial severity in certain registration-districts on the south side of the river; viz., in St. Saviour's, St. Olave's, and St. George's, Southwark, in Bermondsey, Newington, Lambeth, Wandsworth, Camberwell, and Rotherhithe." He next proceeds to show that the conditions of these populations were precisely the same save in the quality of the water consumed in different households. "For throughout those southern districts of London, two great competing water companies had in past times canvassed house by house for their customers; their rival mains were still branching in the same area, often running parallel in the same streets; and during the late invasion of cholera, these two systems of pipes were respectively charged with very different waters.

"If, during the epidemic prevalence of cholera persons consuming pure water are less liable to suffer the disease than persons consuming foul water, surely there might be expected some striking difference between the death-rates of two populations respectively drinking from the Thames at Ditton and from the Thames at Battersea.

"And such were the sources of supply of the two companies referred to; the Lambeth Company pumping from the higher part of the river, the Southwark and Vauxhall Company from the lower; the former furnishing as good a water as any distributed in London, while the latter was purveying perhaps the filthiest stuff ever drunk by a civilized community. . . In the 24,854 houses supplied by the Lambeth Company, comprising a population of about 166,906 persons, there occurred 611 cholera deaths, being at the rate of 37 to every 10,000 living. In the 39,726 houses supplied by the Southwark and Vauxhall Company, comprising a population of about 208,171 persons, there occurred 3,476 deaths, being at the rate of 130 to every 10,000 living.

"The population drinking dirty water accordingly appears to have suffered three times as much mortality as the population drinking other water."[1]

(381) *The Broad Street Pump.*

It was also in the epidemic of 1854 that the report of the water supply of the Broad Street pump exercised much influence on popular and scientific opinion. The water in the well, which was undoubtedly contaminated with sewage, was said to have been specifically polluted by the cholera excreta of a child who suffered from cholera from August 28th to the 30th. The cases of sickness and deaths among the consumers of this pump water are given as follows:—

1854.		Attacks.	Deaths.
August	28.	Child attacked.	
,,	29.	1	1
,,	30.	8	2
,,	31.	56	3
September	1.	143	70
,,	2.	116	127
,,	3.	54	76
,	4.	46	71
,,	5.	36	45
,,	6.	20	37
,,	7.	28	32
,,	8.	12	30

[1] *Report on Cholera Outbreak, St. James's, Westminster.*

(382) *Lessons Learnt from the* 1849 *and* 1854 *Epidemics.*

The total advance in knowledge of the etiology of cholera derived from the 1849 and 1854 epidemics may be summed up in the words of Dr. Farre, "The final report of the scientific committee proved conclusively the extensive influence of water as a medium for the diffusion of the disease in its fatal forms. The zymotic theory was established, and Dr. Snow's view that the cholera stuff was distributed in all its activity through water was confirmed."

(383) *The Cholera of* 1866.

In 1866 cholera was again epidemic in England. It had hovered over Europe the previous year. In the autumn of that year, indeed, a few victims of the disease had died in England, and it had been imported into Portsmouth and Southampton. "At Epping in Essex, the Groombridge family, the medical attendant, and a woman who laid out their servant, were killed by cholera in the last days of September and the first days of October." Nevertheless, it was not until July, 1866, that the disease burst in a limited part of the metropolis. Beginning on July 11th, it reached its maximum severity on July 31st, and then its intensity declined; the number of deaths registered in London from cholera was 5,973, from diarrhœa 3,197, and the total number of deaths from cholera in England was 14,378 (1,842 per million), and 17,170 from diarrhœa (1,036 per million). This epidemic was studied with the greatest care by Radcliffe, Parkes, and a number of other well qualified observers, and the reports of Dr. Farre, of Sir John Simon, of Dr. Netten Radcliffe and others on the medical staff of the Local Government Board, are some of the most valuable which have ever appeared upon the subject and will repay perusal.

(384) *The East London Water Company and the Cholera of London.*

Dr. Radcliffe proved that the area of greatest cholera incidence in London almost exactly coincided with the area supplied by the East London Water Company. The map in which the districts are

shaded according to cholera mortality, of the original report, is very striking, and it would be difficult to convince any reasonable person that so close a coincidence was due to chance; still less so, when the description of the condition of the water-works at that time and other facts are known.

The East London Water Works drew their supply from the river Lea, near Tottenham Mills, certainly not at that point a pure stream, and below it nothing but a sewer receiving the sewage of a large mass of the London population. After depositing in subsidence beds, the water went to a series of filtering beds at Lea Bridge, and from Lea Bridge the water was led by a closed iron conduit to two covered reservoirs on the west bank of the Lea at Old Ford. On the opposite bank were two immense reservoirs, the water of which was when required for use sent along an open foul conduit to the filtering beds at Lea Bridge, but it was possible to turn the water unfiltered from the northern uncovered reservoir into the service covered reservoirs. A careful examination also proved that all these reservoirs were liable to soakage from the filthy waters of the Lea. The engineer of the Company confessed that at the close of June, or at the beginning of July, unfiltered water was drawn from the northern uncovered reservoir into the covered reservoir to the depth of three inches to supplement a defective supply from the filter beds. It was also proved that the first known cases occurring, in one household June 12th, in another June 26th, got rid of their cholera dejecta undisinfected into drains which went direct into the Lea a little way above the reservoirs. In other words, there was direct evidence of the Lea having been placed under conditions of specific contamination, that this river water could gain access by soakage into the reservoirs, and that one of the reservoirs containing unfiltered Lea water had communicated with the covered service reservoir, and that this water had been drunk by a large population.

It is true there were outbreaks in the same area which did not fit in with this theory, but with regard to these there were possibilities of infection by contact with the discharges of patients either immediately or otherwise, or there was a more or less plausible explanation. On the whole, the water carriage theory was held at that time and is still held to sufficiently explain the epidemic of cholera in 1866 so far as the Metropolis is con-

cerned. This belief was strengthened by the strictly parallel case of Newcastle-on-Tyne. The ordinary death-toll in that city was 11 daily from all causes, but in the height of the cholera epidemic, people were dying from cholera alone at the rate of from 100 to 146 per day. The Tyne Company, running short of water, had pumped in the sewage laden river, polluting their purer supply. The colour of the water is said to have resembled porter. On stopping the drinking of this liquid, and substituting a proper supply, the cholera was stayed.

(385) *The Relation of Altitude to Cholera Mortality.*

The mathematical relation of altitude of cholera mortality had been deduced by Dr. Farr from the lessons of the epidemic, both of 1849 and 1854, in the following terse rule :—" *The mortality of cholera is inversely as the elevation of the people assailed above the sea level,*" but the deviation from Farr's rule in the 1866 epidemic was very wide if applied to the whole metropolis. The mortality from cholera in the lowest lying districts (under three feet above high water mark) was less than in districts at an elevation of from 3 to 10 feet; the greatest mortality occurred at an altitude of from 10 to 20 feet; the next greatest at from 20 to 40 feet; and the number following in order after this at from 40 to 60 feet." Although the rule did not hold good when applied to the whole Metropolis, it did so in the most affected locality. The numbers in the East and North-East districts being 107, 89, 88, 76, 17, 4, from the lowest elevation up to 60 to 80 feet. Mr. Radcliffe remarked upon this that " it would seem as if a certain degree of intensity of prevalence of cholera in the metropolis is requisite before the mortality follows the law as to elevation unfolded by Dr. Farr."

(386) *Mortality of Cholera in Relation to Age and Sex.*

According to Farr, the mean mortality in the last three English epidemics was of males 18·0, of females 17·8 to 10,000 living of all ages.

" The mean mortality from all causes in the three cholera years was, for males, 19·3 in excess, for females, 17·9 in excess of the

average mortality to 10,000 living; so females suffered less than males.

The mortality is higher in boys than in girls at all the ages under 15; at the ages of reproduction, 25—45, the mortality of women, many of them pregnant, exceeds the mortality of men; but at the ages after 65 the mortality of men exceeds the mortality of women.

There is evidently a law of mortality involved in the age independently of sex; thus in the three first lustres of life the deaths of boys to 10,000 living were 31·8, 13·2 and 7·6; of girls 28·4, 12·6, 6·4; and the mean mortalities of the two sexes at the same ages were 30·1, 12·9, and 7·0, which differ little from the series 30·1. 14·5, and 7·0, where the numbers are obtained by assuming that the mortality is inversely as the age, and decreases about 14 per cent. for every year of age, or is less than half at 5–10, and less than a fourth at 10–15, what it was in the first five years of life.

After the age of puberty, or from the age of 15 to 25, the mortality also increases very little; it is 8·1 for males and 7·8 for females; and at the six decennial ages extending from 25 to 85, the mortality increases from 15·4 to 43·6, at a very constant rate, as is seen on comparing the calculated series with that observed in both sexes.[1]

THE DEATHS OBSERVED IN THREE EPIDEMICS BY CHOLERA TO 10,000 LIVING AT EACH AGE.

Ages.	Men.	Women.	Mean.	Calculated series.
25—35	15·2	15·6	15·4	15·4
35—45	19·5	20·2	19·8	19·0
45—55	23·5	23·1	23·3	23·4
55—65	28·4	31·4	29·9	28·9
65—75	35·9	35·4	35·7	35·7
75—85	42·2	44·9	43·6	44·0
85—95	46·0	41·4	43·7	54·0
95 and up	82·4	82·8	57·6	67·0

[1] Let m_x = mortality by cholera at age x, then $r^n m_x = m_{x+n}$ = mortality at age $x + n$. In the series given the logarithm of r is taken as 1·93665. This applies only to the ages under 15. At the ages from 25 to 85, and even upwards, the logarithm of r is 0·00911.

$$r = \left(\frac{35\ 65}{15\cdot4}\right)^{\frac{1}{40}} = \left(\frac{m_{70}}{m_{30}}\right) = 1\cdot0212$$

and logarithm r = 0·00911.

Thus to 10,000 men living of the age of 25 and under 35 the deaths by cholera and choleraic diarrhœa, as above defined, were 15·2; to 10,000 women the deaths were 15·6; and the mean mortality of the two sexes in equal numbers is expressed by 15·4. The mean deaths by cholera at the next age (35-45) were 19·8 to 10,000 living, and so on. The calculated series approximates very closely to the observed facts: it is a series in geometrical progression and may be conceived as representing this principle that human life loses the power of resisting the zymotic life of the cholera epidemic year by year after the age of puberty, or what is equivalent, that the lethal power of the epidemic on the organism increases at the rate of 2·12 per cent. Thus for instance, 1,000,000 persons of the age of 30 are exposed to cholera, and 1,540 of them die; then of the same number of the age 31 exposed to the same epidemic under exactly the same circumstances 1,573 will die, and to 1,000,000 persons of one year of age older, or age 32, the deaths will be 1,606. So some force is taken away from the organism every year of life, every second we may conceive, by which its constituents become less able to resist the action of the cholera leaven. And the diminution of resisting force obeys a law which is of this nature; the loss is an accumulating quantity, and in the end becomes so great as to leave the life at the mercy of other forms of life or of other forces.

Thus the mortality at one age being given, the mortality at any other age within certain limits can be calculated.[1]

(387) *Symptoms.*

Cholera has without doubt a period of incubation, but the difficulty in knowing when the infection first occurred in but a comparatively small number of cases has caused this period to be variously estimated by different writers. The most probable statement is that of Niemeyer, who fixed it at not less than thirty-six hours and not more than three days.[2] The symptoms of cholera vary according to severity, the most severe of all killing at once without intestinal discharge—the so-called "*cholera sicca*"; a less

[1] $m_{60} = r^{30}m_{30} = 28{\cdot}89 \quad 15{\cdot}40r^{30} = 15{\cdot}40 \times (1{\cdot}0212)^{30}$. By logarithms $\lambda 15{\cdot}40 + 30\lambda r = \lambda m_{60} = \lambda 28{\cdot}89$.

[2] Farr, Report on the Cholera Epidemic in England, *Supplement to Twenty-ninth Annual Report of the Registrar-General.* London, 1868.

severe form but yet one in which the symptoms are of the most serious character and a mild form.

There have been many descriptions of the clinical aspects of cholera, but for our purpose the report of Dr. Sutton[1] on the characters of cholera in 1860 will suffice, the more so, as the symptoms of 250 cases were very carefully analyzed, and all these cases occurred in England. Sutton's description is therefore that of Asiatic cholera as seen when imported into England.

In the one case of *cholera sicca* described by Sutton, the history was shortly as follows: A man about 40 to 50 years of age, was seen walking in the public street; he suddenly cried out, put his hand to his belly and fell down. He was conveyed to the hospital without loss of time but died on the way.

The organs were generally healthy. But the duodenum was full of an opaque pale canary-coloured liquid; on following the intestine down the fluid got thinner, until when the ileum was reached it had all the characters of the so-called rice-water discharges. The small intestine was full of fluid. In the large intestine was a large quantity of semi-solid and solid fæces.

In other words in *cholera sicca* the person seems to faint to death without previous diarrhœa or other symptoms, and the only evidence of the cause of death being cholera is the state of the intestines.

Preliminary Diarrhœa.—In a good many cases of cholera there is what has been called "preliminary diarrhœa." Of 41 cases in which diarrhœa preceded the choleraic symptoms, in 12 the diarrhœa had been present from periods varying from 12 hours to 24. In 13 the diarrhœa had preceded from 33 hours to 2 days; in the rest the periods were from 3 days up to 8 weeks. It is highly improbable that the longer periods (anything indeed over 3 days) had a direct connection with true cholera; cases in which diarrhœa, for instance, preceded the cholera symptoms for several weeks must have been ordinary diarrhœa on which the cholera grafted itself; it is reasonable to suppose that in cholera epidemics persons with disordered intestines are more likely to be infected than those who are in health; it is even a question whether even the shorter periods all belong to cholera. This supposition also affords a plausible explanation of the undoubted good that the early treat-

[1] *Ninth Report of the Medical Officer of the Privy Council.*

ment of so-called preliminary diarrhœa does in the prevention of cholera extension. It may well be that a congested intestine affords the best soil for the cause of cholera, and by curing the congestion, the healthier secretions are able to destroy any contagium which may be swallowed.

The symptoms more particularly referable to cholera usually commence with great suddenness and are generally divided into a cold and a hot stage; the cold stage being that in which there is more or less collapse. The hot stage is the stage in which reaction sets in. The average duration of the cold stage in Sutton's cases was from 20 to 30 hours. The disease commences with frequent vomiting and violent purging, and the poison elaborated in the intestines is conveyed by the circulation throughout the muscular system, and fearful cramps and spasms result. The cold stage fully established, the eyes are sunken, the lips vivid, the tongue blanched, and the pulse may with difficulty be felt at the wrist. The voice is a whisper, but intelligence remains. The temperature (external) is always below normal, falling rapidly from 5 to 7 degrees below the standard, and in the reaction the temperature then is with few exceptions either normal or a little above. It hence follows that the so-called hot stage, is only a stage in which the surface temperature of the body is again approximately that of health, the term is a bad one, suggesting fever which does not exist. From first to last cholera is a depressor of vital function; but when the maximum temperature during the whole time is steadily below normal, such cases are likely to be fatal. The cold stage passes rapidly either to death or recovery. If the latter, either the patient sinks into a quiet sleep, or the countenance begins to look more natural, the pulse more perceptible, the skin warmer, the cramps and sickness with the purging stop, and gradually the functions are again resumed.

(388) *Post-mortem Appearances.*

The post-mortem appearances of cholera are seen in their most characteristic form in rapid cases which have died during the cold stage. The chief signs of cholera are to be found in the condition of the lungs and intestines. The ultimate tissue of the lungs is remarkably dry and light, the lungs weigh less than

normal, the right side of the heart is gorged with blood, and of course the vena cava, and the pulmonary arteries are also distended, the left or systemic side and the aorta and its branches are on the contrary comparatively empty.

The mucous membrane of the ileum, especially that of the lower part, is congested; there is loosening and detachment of the epithelium of the surface and of that lining the glands of Lieberkühn. There is a special congestion around Peyer's lymph glands. These alterations according to Koch are the effect of the comma bacillus which secretes a special chemical ferment. The changes are most pronounced in the lower part of the ileum, higher up the changes diminish in intensity and finally disappear in the upper part of the small intestine.

(389) *Bacteriology of Asiatic Cholera.*

In 1848 Pacini had described "vibrios" in the intestinal discharges of cholera patients. Klob also, in 1867, appears to have laid great stress on certain small organisms that he described, but whether these minute bodies described by Pacini and by Klob were identical with the comma bacillus of Koch is uncertain; the microscopes of that time were inferior in definition and in power to those now used, and the knowledge of bacteria of the crudest; however this may be, and whether the organisms described by Koch have been previously discovered or not, to Koch and the German cholera commission belong the entire credit of discovering that a particular micro-organism is always associated with Asiatic cholera, and with no other disease. This discovery was the outcome of the work done by the commission in the years 1883-4 in their extensive inquiry into cholera in Egypt, Calcutta, and France.

During the acute stage of cholera there are to be found in the rice water discharges minute bodies, which Koch calls, on account of their shape, "comma bacilli;" these by some are regarded as a spirillum (*spirillum choleræ Asiaticæ*), by others as vibrios. In size they are of the same thickness as the tubercle bacillus but only half their length; they present the appearance of little curved rods, and so far resemble a comma that the latter is a good name. They are actively motile and liquefy the gelatin as most of the

moving micro-organisms do. The commas multiply by transverse division and after division the two offsprings may remain joined end to end in the shape of an S, and by further division they may grow into a spiral or wavy form. "It grows in and liquefies slightly alkaline gelatin; more slowly in neutral, scarcely at all in slightly and not at all in markedly acid gelatin. On a gelatin plate cultivation the individual colonies are round, lie in a funnel-shaped cavity, when viewed by transmitted light and magnified, they look like ground glass; the edge of the colony is finely notched. In a gelatin tube a funnel-shaped cavity forms at the top of the puncture made by the inoculating wire and lying in this cavity there is what looks like an inverted air bubble, with its top on a level with the surface of the jelly, and open to the air, along the puncture the gelatin liquefies, and in this may be seen with the naked eye the whitish mass of colonies more particularly at the lowest part; in from three to four weeks liquefaction spreads to the whole mass, the bacilli falling to the bottom as a greyish white sediment having a faint orange tint in certain lights, and if undisturbed, a perfectly transparent liquid separates a whitish scum on the top from the sediment below."[1] In gelatin cultures growth is most rapid at from 80° to 100° Fahr.; it grows slowly at 60°, and even at 50°, but below 50° it does not grow; it is not destroyed at a freezing temperature. If kept moist it will live for months; drying always destroys it,[2] for hitherto no spore or resisting forms have been discovered. Milles and Macleod have, it is true, seen an appearance like endospores, and such bacilli bore forty-eight hours drying and yet recovered, but with longer drying death of the commas always resulted. In the absence of air, growth on gelatin ceases. The "commas" also grow well on agar-agar, on mucus flakes taken from the intestine, on potato, and in broth.

The opponents of the theory of the part which Koch and the German school assign to the comma spirillum in relation to cholera

[1] An Enquiry into the Causation of Asiatic Cholera, by Neil Macleod, M.D., and Walter J. Milles, F.R.C.S., *Public Health*, vol. i. p. 322.

[2] In Berckholtz's elaborate research (*Arbeiten aus dem Kaserl. Gesundheitsamte.* Bd. V. 1) on the effect of drying the cholera bacillus, he found cultures containing exclusively commas and S forms somewhat more resistant than cultures which contained no S forms. He considers it very probable that in nature the slimy mass of a culture may form a sort of protective capsule, and thus prevent the full drying and preserve the life of some of the commas. This he deduces from the different behaviour of the bacillus when dried on silk threads and on glass.

make the most of the easy destructibility of this micro-organism; not alone does drying destroy, but it falls a victim to feeble disinfectants, and, as before mentioned, even the acids of the guinea-pig's stomach effectually dissolve it. Surgeon-Major Cunningham [1] has shown that when cultivations of commas are added to water or to soil, the schizomytes attack the commas, and they tend to rapidly disappear. For example, Cunningham added to a pretty good drinking water cultivations of the comma bacillus; in one experiment none were found at the end of four days, in another all had disappeared at the end of five days. In yet another series of experiments excreta-polluted water was used, and all commas disappeared in a period varying from four to nine days, but when the water had been previously boiled the commas added could be found up to the twenty-fifth day.[2] In ordinary garden soil the commas could be discovered from ten to twenty-six days after contamination. Garden soil previously polluted with fæces and then contaminated with commas, was more destructive, and the commas were not found in periods from six to nine days, a few afterwards, but if the same garden soil polluted with excrement was first sterilized by heat and then the comma cultivations added they were still present after forty-seven days. Kitasayo[3] also found that ordinary fresh unsterilized fæces infected with the bacillus retain but for a short time living comma bacilli, but if the fæces are sterilized by steam or other means, the destruction is far less.

In other words, under ordinary conditions the agency of destruction is so powerful that it would seem impossible, if the cause is the comma spirillum choleræ, for cholera to be truly endemic in a country. Dejections cast into soil or water fall a prey to other micro-organisms, and contrary to the teachings of so many observers, Cunningham's experiments would tend to prove that the fouler the soil, the more chance of inimical schizomytes.

But on the other hand, Nicati and Rietsch have shown that the commas could live in the water at the port of Marseilles for eighty-one days, and in the absence of other organisms the life of

[1] *Scientific Memoirs by the Medical Officers of the Army of India.* Edited by Sir Benj. Simpson. Part iv. 1889.

[2] Macnamara arrived at very similar conclusions. He considered water polluted with cholera excreta ceased to become dangerous when after successive generations of animalcules, confervæ appeared; this in India happened about the third day.

[3] *Zeitschrift f. Hygiene.* Bd. V. heft 3.

the comma may, according to Koch, be prolonged for more than 144 days. It is a question whether the observations of Cunningham are really so much against the comma bacillus as a cause of endemic cholera as that observer appears to think, the life history of the organism is not yet fully worked out, it is known to have more than one form, and it has not yet been studied under all possible conditions.

The observations of Ferd. Hueppe,[1] recently published, show that the "commas" when first expelled from the body, having developed under anaërobic conditions, are tender and easily destroyed, but when exposed to air or oxygen they become more resistant and act more energetically. The practical importance of these facts relative to early disinfection is obvious. Hueppe at the same time points out that this difference of vigour in the anaërobic and aërobic condition satisfactorily explains the infrequency of direct infection.

(390) *The Bacillus of Finkler and Prior.*

A bacillus was discovered by Finkler and Prior[2] in cholera nostra which bears a superficial resemblance to the spirillum of cholera, but it may be readily distinguished by its method of growth in gelatin, the comma bacillus, when inoculated by the stab method shows at the end of twenty-four hours a white track along the course of the stab; on the other hand, under the same conditions, the Finkler-Prior bacillus liquefies the gelatin much quicker, and throughout the whole extent, while the comma only shows a little liquefied well on the top exposed to the air. Hovorka and F. Winkler,[3] by using the albumen of plovers' eggs coagulated at 90° C. and sterilized by exposure to a heat of from 60° to 70° for twenty minutes on three successive days have obtained a culture medium by the aid of which they believe they have a new distinction between the organisms mentioned. A stab culture of Koch's bacillus in this medium soon shows a surrounding layer which reflects light stronger than the rest of the albumen, and hence appears clearer; on observation with a lens are seen greyish

[1] *Präger med. Wochenschrift*, March 19, 1890. *Public Health*, vol. iii. p. 87.
[2] *Ergänzungshifte zum Central. f. Allgemeine Gesundheitspflege.* Bd. I. 1865.
[3] *Allgemeine Wiener med. Zeitung.* XXXIV. Jahr. No. 23. *Public Health*, vol. ii., p. 114.

crowds of colonies, which on the third day occupy the whole breadth of the needle track. There is no real liquefaction although there may be here and there incipient signs of it. The Finkler-Prior bacillus shows a liquefaction around the colonies by the second day. This becomes so decided that on the third day the mass of the albumen is detached from the walls of the test tube. By the sixth or seventh day the albumen is coloured yellow —the colour increases in depth until the whole is changed into yellow brown—then the albumen becomes again solid. It is this rapid liquefaction, the yellow colour and subsequent "setting" again of the albumen which forms the distinguishing mark between the two micro-organisms.

(391) *The Recognition of the Comma Bacillus by Chemical Tests.*

Chemical tests have also been proposed for the recognition of the comma bacillus. Otto Bujwid[1] states that when the cholera comma colonies have grown to white points, and beef broth is inoculated with one of them and cultivated for twelve hours at 37° C. the liquid takes a rose colour on the addition of hydrochloric acid. M. J. R. Petrin[2] has also shown that the comma bacillus reduces nitrates to nitrites; but these chemical effects can only be used practically when further research has shown that they are peculiar to this bacillus; in the meantime they must be considered as only confirmatory of the other characters. There is a spirillum (*spirillum sputigenum*) to be found in saliva and carious teeth, which is morphologically similar to Koch's bacillus, but it is difficult to cultivate, and is apparently a distinct form; there is also another spirillum which is something like Koch's commas which has been isolated from cheese; this spirillum is smaller than the cholera spirillum and has a different method of growth.

(392) *Klein's Objections to the "Comma" Theory.*

It remains to be added that Klein[3] has criticized the comma theory, and has also repeated Koch's experiments without confirming them. One of the arguments against Koch's theory, according

[1] *Zeitschrift f. analytische Chemie*, vol. xxvi.; *Public Health*, vol. i. p. 93.
[2] *Centralblatt f. Bakteriol in Parasitenkunde.* Bd. V. 18; *Public Health*, vol. ii, p. 56.
[3] *Fifteenth Annual Report of the Local Government Board. Supplement*, 1886.

to Klein, is that in all infectious diseases produced by a micro-organism, the micro-organism is found in the blood or tissues; this no longer holds good, that is if the observations on diphtheria by the French school and by Loeffler are correct; in that disease a micro-organism grows on and within the mucous tissue, is entirely local, and yet affects profoundly the system. Klein views the comma bacillus as accidental, probably being always present in small numbers in the intestines, and then under favouring conditions multiplying; he acknowledges, however, the almost constant presence of the commas in cases of true cholera. Neither the experiments nor the arguments of Klein are sufficiently conclusive, and on the whole the current of scientific opinion leans to the side of Koch.

(393) *Experiments on the Communicability of Cholera before the Discovery of the Comma Bacillus.*

1. Injections of cholera blood into the veins.

In 1831 Magendie[1] injected an ounce of cholera blood into the veins of a dog without effect. When eight ounces were employed the dog became affected with cholera-like symptoms and died; the post-mortem appearances had some similitude to those found in cholera. In 1836, a Venetian physician, Dr. Giacinto Namias, and afterwards Semmola,[2] inserted blood coagula taken from the hearts of persons dead from cholera, beneath the skin of rabbits; the effects as might be expected were uncertain and contradictory. Marshall,[3] in 1849, made seven experiments with cholera blood. He injected the blood into the veins of animals; the effects produced were in every instance considered by the experimenter as sufficiently explained by the assumption that dead blood had been introduced charged "with the products of its own decomposition." A more important experiment was made subsequently by the same observer: blood was taken from six living patients, and after being defibrinated and slightly diluted with water, was injected from 20 to 30 minutes after abstraction into the veins of animals; the quantity injected was from four to six drachms when dogs were employed, and about three drachms for cats and rabbits.

[1] *Leçons sur le Choléra Morbus*, 8vo. Paris, 1837.
[2] *Annali Universali de Medicina, compilati da A. Omodel*, t. 77–78.
[3] *Brit. and For. Med.-Chir. Rev.* vol. xi. 398

Into the veins of two dogs were injected larger quantities of blood taken from patients affected with other diseases to serve as a control. One only of the dogs exhibited any very decided symptoms. This dog was prostrated for many hours, the bowels were slightly relaxed and there was loss of appetite. The following day the animal was well, the other animals suffered very slightly. Injections of fresh living cholera blood by Namias, Carl Schmidt,[1] and by Jos. Meyer[2] into the veins of dogs, rabbits, and cats, all gave negative results.

The general result of all the experiments is that although large quantities of blood may produce symptoms, yet that the cause of cholera is not in the blood, or if in the blood cannot affect animals.

II.—Injections of the intestinal discharges of cholera.

Mr. Marshall injected into the jugular veins of cats and dogs filtered rice water discharges. The animals were languid and distressed and had slight purging for two days.

III.—Introduction of the intestinal discharges into the stomach of animals.

By far the best class of these cases are those of unintentional experiment as when dogs have devoured human cholera vomit or excreta. A well authenticated case is recorded by Meyer.[3] A large house-dog ate portions of his master's cholera stools. 10 hours after, the dog vomited a pale-coloured liquid and discharged a yellowish, offensive, watery dejection. In seven hours he was dead. Hertwig made the post-mortem. A rice-water looking liquid flowed from the mouth, and was contained in large quantity in the alimentary canal. The intestines were congested and the lining membrane covered with white flaky mucous; Peyer's patches were reticulated and surrounded by areolæ of injection. Von. Hildenbrandt[4] has collected a large number of instances in which domestic animals suffered from a disease resembling cholera in places where cholera was epidemic. Marshall made nine experiments in which vomited or dejected matters were introduced into the stomachs of animals. The experiments were made

[1] C. Schmidt, *Charakteristik der epidemischen Cholera gegenüber verwandten Transudations-anomalien.* Leipzig, 1850, p. 79.

[2] *Virchows' Archiv. f. Pathol. Anat.* Bd. iv.

[3] *Op. cit.*

[4] *Oester. med. Jahrbucher.* Bd. xvii., xviii. Vienna, 1838, 1839.

on dogs, cats, guinea-pigs, and rabbits. Two of the three dogs died, one recovered, the symptoms and the post-mortem appearances bore some likeness to cholera.

In 1850 Jos Meyer[1] made a similar series of experiments on dogs. Out of six dogs, one only yielded negative results. The five remaining suffered from diarrhœa, three died, the post-mortem appearances were not dissimilar from those of cholera.

In 1853 Dr. Lauder Lindsay,[2] then resident physician to the cholera hospital, Edinburgh, induced a fatal diarrhœa among dogs by confining them for a length of time in a small room having a capacity of 1,050 feet, on the floor of which the ejections, excreta, and urine of cholera patients were strewed; the animals were also fed with the blood, urine, and other fluids and solids obtained from the bodies of persons who had died of cholera.

IV.—Administration of small quantities of dried excreta.

Thiersch[3] made a careful series of experiments on white mice. He soaked filter-paper in rice-water cholera discharges, allowed the paper to dry, and fed white mice with paper thus prepared. The experiments were made in several series, the discharges were taken from different parts of the intestine, and allowed to stand and decompose during different periods of time. He found that the mice were not affected by eating filter-paper soaked with the fresh discharges; but that if the discharge was allowed to decompose for from two to six days, it induced a fatal diarrhœa.

Dr. Burdon Sanderson[4] made a very exact series of similar experiments to those of Thiersch. He found that the rice-water discharges allowed to stand for from three to four days produced a cholera-like disease among mice, and that the disease could be communicated from one affected animal to another of the same species.

It has been the custom of late years to pass by these experiments of Thiersch and Burdon Sanderson, but the results were remarkable, and they deserve repetition aided by bacteriological investigation. There are also reasons to consider the celebrated instance of infection from water described by Macnamara[5] in the

[1] *Virchows' Archiv. f. Path. Anat.* Bd. iv. 31.
[2] *Ed. Med. and Surg. Journal.* Vol. lxxxi.
[3] *Haupt Bericht uber die Cholera-Epidemic des Jahres*, 1854. Munich, 1857
[4] *Ninth Rep. Med. Officer to the Privy Council.*
[5] Macnamara, *A Treatise on Asiatic Cholera*, 1870, p. 381

light of an experiment. "A small quantity of the dejecta of a cholera patient was known to have been washed into a vessel containing water, the mixture after being exposed to the heat of the sun for one day, was swallowed by 19 men on the following morning; within three days five of these were affected with cholera."

(394) *Modern Experiments on Animals with Cultivations of the Comma Bacillus, &c.*

Nicati and Rietsch, injected directly into the duodenum of dogs and guinea-pigs cultivations of the comma bacillus, they induced a disease very much like cholera. This experiment was repeated by Babes, Flugge, and Watson Cheyne, and the results confirmed. At first Nicati and Rietsch ligatured the bile duct, but subsequently this was not found necessary. Koch also repeated this experiment and declared that out of 18 guinea-pigs into which he had injected the comma bacillus into the duodenum, 13 had died of cholera. At the same time control experiments were not omitted, and cultivations of a number of other pathogenic organism were injected into the duodenum of guinea-pigs; all the control animals lived. In 1885 Koch announced that he had succeeded in reproducing the disease in the guinea-pig without opening the animal's abdomen. He had studied the digestive process in the guinea-pig and found that the stomach reaction was always acid; this acidity had probably destroyed the commas when the latter were given by the mouth. To overcome this, he had injected into the stomach a solution of soda; in this way the commas were made to pass along into the small intestine, nevertheless, there was mostly failure. This he ascribed to the rapid peristalsis of the first portion of the rabbits' intestines, the commas were hurried on, before they had time to multiply. He found that coloured foods passed from stomach to coecum in a few minutes. To overcome this, he dosed the animals with opium (the opium being injected into the peritoneal cavity). "I apply," says Koch, "opium in the form of tincture, in the dose of 1 c.c. to every 200 grms. weight of the animal. After this dose there follows in a very short time deep narcosis, after which the animal is as lively as before. With a combination of soda solution and cholera broth,

and after injection of opium tincture, experiments were made on 35 guinea-pigs; of these 30 died of cholera. The symptoms during life and the appearances after death were identical with those found in guinea-pigs which had received duodenal injections."[1]

Dr. Neil Macleod[2] has repeated and extended these experiments of Koch. In thirty-four experiments on guinea-pigs with cultivations of comma bacilli, all were successful in producing a cholera-like disease; in twenty-one of the animals the result was fatal. Eleven control animals treated exactly in the same way, but receiving sterilized broth, recovered, and showed no symptoms. Three animals also receiving soda solution alone, were in no way affected.

From one of the animals that died after a dose of cholera material the small gut contents were collected in a sterilized vessel and injected in doses of 2 c.c. into the stomachs of two other animals. These two animals died and the contents of their small intestines were used in the same way, and so on through ten generations. Of twenty-one animals thus treated two recovered, nineteen died. The dose varied from ·5 to 2·5 c.c.

The post-mortem appearances in the guinea-pigs experimented on by Macleod are thus described:—"The blood was fluid, thicker and darker than natural; the tissues of the thoracic and abdominal walls were markedly dry; the small intestine was throughout distended, congested, and paralyzed-looking, and occupied a much larger proportion of the abdominal cavity than usual. The coecum was distended with fluid or semi-fluid contents. If the animal had died early the fluid was not quite clear in the small gut, there being present traces of food, still the watery character was very manifest and mucous flakes were abundant. If the animal had died on the second or third day, no food remains were to be seen, and the fluid in the small gut was the counterpart of the typical cholera stool in man. In either case the comma bacilli were demonstrated microscopically and by cultivation as in man. While the organism in the broth injected could be frequently counted in a microscopic field, in a drop of the small bowel contents from an animal having received such broth, the bacilli might be so numerous that counting them without dilution of the fluid examined

[1] *Ber. Klinische Wochenschrift*, Sept. 21, 1885.
[2] *Public Health*, 1888, vol. i. p. 322.

was an impossibility. On floating the bowel on water the stripping of the epithelium could be well demonstrated."

The conclusions arrived at by Dr. Neil Macleod and Walter J. Milles, F.R.C.S. Eng., in their able research, are as follows:—1st, the comma bacillus of Koch is invariably present and associated with certain changes in the small intestine, in cases of Asiatic cholera; 2nd, there is no evidence to show that it is a normal inhabitant of the human alimentary canal, and therefore no proof for the assertion that it is a result of the disease. 3rd, the means used to introduce the comma bacillus into, and those used to lessen the peristalsis of, the small intestine of the guinea-pig cannot be regarded as causing appearances like those of Asiatic cholera, or as causing the death of the animal, far less a mortality of over 60 per cent.; 4th, pure cultivations of the comma bacillus introduced into the stomach under the precautions described, are pathogenic to the guinea-pig; 5th, injected with similar precautions, the contents of the ileum from those animals killed by injections of pure cultivations of the bacilli, act in the same manner as pure cultivations of that organism; 6th, the organism multiplies in the small intestine of the animal, and there are associated therewith changes similar to those in man in Asiatic cholera."

(395) *Propagation of Cholera by Water and Otherwise.*

In the brief history of cholera in England, sufficient examples have been given as to the propagation of cholera by water. Koch considers that the cholera contagium is in all cases *swallowed*, the commas may be in the water or may be in food, but it must be *swallowed*; he would consider the possibility of it being propagated by sewer gas problematical, and that it can be blown about as dust and breathed in that form, would be negatived by the experimentally ascertained fact that drying is fatal to the bacillus. In respect therefore to the propagation of cholera in other ways than by swallowing the contagium in food and drink, the history of the introduction of cholera into Southampton as described by the late Dr. Parkes in 1866 is full of interest.[1] On the 10th of June, 1866, the P. and O. steamship *Poonah* arrived from Alexandria, Malta,

[1] *Ninth Rep. of the Med. Officer of the Privy Council.*

and Gibraltar, having on the preceding day lost a man from cholera; the cause of the outbreak was attributed to foul water taken in at Gibraltar; the history clearly shows that the severe diarrhœa prevailing on board the steamship was confined to a certain section of the crew who drank the water from a particular tank, and this water was found on analysis to be much polluted. However this may be, it is certain that eight or ten people suffering from "choleraic diarrhœa were landed in the town and dispersed in various quarters, and that their dejections passed into the sewers."

There were doubtful cases of cholera on June 12th, June 15th, and July 6th in Southampton, but the disease definitely and unmistakably broke out from July 6th to the 13th: up to the evening of the 17th no less than thirty-five to thirty-seven deaths had occurred. By the 4th or 5th of August the epidemic was virtually over.

Dr. Parkes considered that the outbreak probably introduced by the *Poonah* had no connection with the water supply of Southampton. "The whole of Southampton is supplied from a town reservoir; the supply is continuous; there are no cisterns. If the water was the cause it must have affected the town generally; there are nearly 50,000 people in Southampton, and there were only 320 cases of cholera scattered over nearly three months. It is impossible to suppose that 49,700 people who used the water could have escaped had the water been bad." . . . "The disease was certainly worst in the most unhygienic parts of the town, but was not confined to these, for good houses in airy situations in the low part of the town suffered and some of the worst localities remained free."

After a very careful consideration of all the possible causes, Dr. Parkes was inclined to accuse the sewer system. "Almost all the town is sewered, but unfortunately on a bad principle, a very large network of sewers being provided towards the outlet in order to act as a reservoir during certain periods of the tide. There is thus a great stagnancy during several hours of the day, and indeed at some periods it is probable that there is very little flow even for long periods. The ventilation is very imperfect, being provided for by gratings in the road, and as these give off offensive effluvia, they are continually stopped up with pieces of wood by the inhabitants of the neighbouring houses. The consequence is

that the gases are thrown back upon the houses and force their way through the very imperfect traps."

From causes detailed in the original report, the sewers at the time of the *Poonah's* arrival were in a particularly clogged and offensive state, and the sewage pumping at the western station had been discontinued. "In the beginning of July the pumping of the western shore sewer into the outlet sewer was recommenced." . . . "All the immense mass of sewage from the western sewers was raised and then poured down an open conduit into the outlet sewer. Tons and tons of sewage were thus daily pumped up, and frothing and agitated by this churning were poured like a cataract down the open channel for some 8 or 9 feet. The effluvia disengaged from this quantity of seething sewage was overpowering. It spread all over the neighbourhood, and was bitterly complained of in the adjacent houses. The effect, however, would not be confined to them; the cloud of effluvia thus thrown up must have extended far beyond the point where it was detectable by smell. The occurrence of some early cases of cholera in clean, airy houses near this pumping station was the first thing that called attention to it, and it was then found that diarrhœa was beginning to prevail in several of the adjacent houses. There was no local cause to account for these attacks except the great effluvia thus disengaged." But the most striking point in the history is when a closed iron pipe was substituted for the open conduit and carbolic acid largely used as a disinfectant, there was an immediate diminution in the cholera outbreak; the alteration took place on the 19th of July, and Dr. Parkes says, "On the 24th of July the worst was over."

It is therefore only reasonable to believe that the incidences as to time and place were not accidental, but that the state of the sewers and the cloud of spray and effluvia at the pumping station had a very definite connection with the Southampton cholera epidemic of 1866.

(396) *Propagation of Cholera by Clothes Soiled with the Discharges.*

There are also numerous cases on record in which those who have washed the undisinfected linen of cholera patients have been attacked with cholera, and the following incidents are types

scattered in literature of cases in which cholera has been conveyed to distances by undisinfected clothes.

In 1854 cholera broke out in a village in Bedfordshire, two fatal cases occurred. The first case was that of a man whose son had died in London a week or two before of cholera, and whose clothes (undisinfected) were sent down to the country. The man unwrapped the clothes himself, was seized with the disease, and died in a short time. This case was the nucleus from whence the others took their infection.[1] At Leistheim, near Munich, the first case of cholera was in the house of a labourer, one of whose daughters was in service at Munich, the latter sent her parents clothes belonging to a family some member of which had died of cholera. These old clothes were at once appropriated and worn. Three days afterwards (September 21st) the father and mother were seized with cholera, and died on the 22nd and 23rd; other members of the family took the disease.[2]

(397) *Pettenkofer's Theory.*

Pettenkofer's theory of the spread of cholera is that it is intimately connected with the composition of the soil. The essential elements as to season and locality are:—(1) The physical composition of the earth and subsoil of the dwelling. (2) The moisture of the soil and its changes; this moisture he designates by the collective term "ground water;" to these must be added the presence of nourishing substances in the soil suitable for the nourishment of the lower organisms. (3) The specific germ; he is also inclined to lay stress upon individual predisposition. The rise and fall of the ground water is but an index of the moisture of the earth; the most dangerous time for cholera, according to Pettenkofer, is when the ground water, having risen above its usual level, sinks or is sinking. The later epidemics and the outbreaks on vessels at sea, give but moderate support to this theory.

(398) *Preventive Measures as formulated by Koch.*

In the conference on cholera at Berlin, 1885, Koch sketched the following scheme as to preventive measures.[3] The preventive

[1] *On Malaria and Miasmata*, by Dr. Barker, F.R.S. Macnamara, p. 162.
[2] Quoted by Macnamara.
[3] *Berliner klinische Wochen.*, Sept. 21, 1885, No. 37, a. u. b.

measures against cholera must in the first place be referred to the fact that the infection is produced in man, and is contained in the evacuations. In order therefore to make the infectious matter harmless, the dejecta are to be mixed with suitable disinfectants. Carbolic acid is the most suitable, a five per cent. solution, mixed with an equal bulk of either the dejecta or the vomited matters is sufficient to destroy fully the cholera bacillus.

If it were possible to collect all the excreta of the sick in vessels and to immediately treat them with disinfectants, then the destruction of the infectious matter would be simple and certain, and better results would be obtained with disinfectants than now, but any one who has to do with cholera patients knows that only a portion of the excreta actually goes into the vessel, the rest is on the bed, the earth, the clothing, and the hands of the sick and his attendants. Hence all things which either can be soiled or are soiled by the dejecta must be disinfected.

The soiled linen must be put into a solution of 5 per cent. carbolic acid or other disinfecting fluid. Where clothes need not be immediately sent to the wash but may remain several days in the disinfecting fluid, weaker solutions may be used. Clothing, bedding, and mattresses, which cannot well be disinfected by fluid disinfectants, should be submitted to steam in a disinfecting apparatus. Things, as ambulances and the like, which can neither be disinfected with fluid disinfectants nor by steam should not be used for some time, but well aerated, for if the bacillus is dried it is destroyed. Where disinfecting apparatus and appliances are not at hand, things of little value may be burnt, those of more value simply exposed to the air for a long time.

The aeration and drying through heat is the most suitable for the disinfection of the sick room. Disinfection with gaseous reagents especially with sulphurous acid gas, later researches have shown to be uncertain and therefore not desirable. The nurses are to wash their hands often, never to touch the mouth with the hands, and if the hands become soiled with the discharges they must be disinfected with carbolic acid or corrosive sublimate solution. Eating in the same room in which are persons sick of cholera must be specially avoided, as in the dwellings of the poor so often happens.

But with all the above-named precautions complete success may

not be attained because these precautions can only be taken in the serious cases which are recognized as cholera. The numerous slighter attacks which are not recognized as cholera, and which seek no medical aid, are not amenable to these regulations. Like the ambulatory form of scarlet fever, measles, &c., these are probably still more dangerous to the public health than the pronounced cases of cholera, since the dejections of these cases have been ascertained to contain the comma bacilli, yet the sick are enabled to go about their occupations, and to carry from place to place their infection unsuspected.

If we turn now to the accepted English method of prevention as drawn out by the present medical officer to the Local Government Board, the directions only differ as to detail, irrespective of whether Asiatic cholera is produced by "commas" or not; stress is laid by both the English and German school on the special danger of the excreta, the importance of cleanliness, of disinfection, and of general hygiene.

(399) *Official Memorandum as to Prevention of Cholera.*

PRECAUTIONS AGAINST THE INFECTION OF CHOLERA.

1. The Order of the Local Government Board of July 12th, 1883, now in force, gives certain special powers to the Sanitary Authorities of the sea-coasts, enabling them to deal with any cases of cholera brought into port, so as to prevent as far possible the spread of disease into this country; but as cases of choleraic infection have widely different degrees of severity it is possible that some such cases slightly affected will notwithstanding the vigilance of local authorities be landed without particular notice in English sea-board towns, whence they may advance to other and perhaps inland places.

2. Former experience of cholera in England justifies the belief that the presence of imported cases of the disease at various spots in the country will not be capable of causing much injury to the population if the places receiving the infection have had the advantage of proper sanitary administration, and in order that all local populations may make their self defence as effective as they can, it will be well for them to have regard to the present state of knowledge concerning the mode with which epidemics of cholera at least in this country are produced.

3. Cholera in England shows itself so little contagious in the sense in which small-pox and scarlet fever are commonly called contagious, that if reasonable care be taken where it is present there is almost no risk that the disease will spread to persons that nurse and otherwise attend closely on the sick; but cholera has a certain peculiar infectiveness of its own, which where local conditions assist, can operate with terrible force and at considerable distances from the sick. It is characteristic of cholera (and as much so of the slight cases where diarrhœa is the only symptom, as of the disease in its more developed and alarming forms) that all matters which the patient discharges from his stomach or bowels are or can become infective. Probably, under ordinary circumstances, the patient has no power of infecting other persons except by means of these discharges; nor any power of infecting even by them except in so far as particles of them are enabled to taint the food, water, or air, which people consume. Thus, when a case of cholera is imported into any place,

the disease is not likely to spread unless in proportion as it finds, locally open to it, certain facilities for spreading by indirect infection.

4. In order rightly to appreciate what these facilities must mean, the following conditions have to be borne in mind—first, that any choleraic discharge, cast without previous thorough disinfection, into any cesspool or drain or other depositary or conduit for filth, has a faculty of infecting the excremental matters with which it there mingles, and probably, more or less, the effluvia which those matters evolve; secondly, that the infective power of choleraic discharges attaches to whatever bedding, clothing, towels, and like things, have been imbued with them, and renders these things, if not thoroughly disinfected, as capable of spreading the disease in places to which they are sent (for washing or other purposes) as, in like circumstances, the patient himself would be; thirdly, that if, by leakage or soakage from cesspools or drains, or through reckless casting out of slops and wash-water any taint (however small) of the infective material gets access to wells or other sources of drinking water, it imparts to enormous volumes of water the power of propagating the disease. When due regard is had to these possibilities of indirect infection, there will be no difficulty in understanding that even a single case of cholera, perhaps of the slightest degree, and perhaps quite unsuspected in his neighbourhood, may, if local circumstances co-operate, exert a terribly infective power on considerable masses of population.

5. The dangers which have to be guarded against as favouring the spread of cholera infection, are, particularly, two. First, and above all, there is the danger of water supplies which are in any (even the slightest) degree tainted by house refuse or other like kinds of filth: as where there is outflow, leakage, or filtration from sewers, house drains, privies, cesspools, foul ditches, or the like, into springs, streams, wells, or reservoirs from which the supply is drawn, or into the soil in which the wells are situated: a danger which may exist on a small scale (but perhaps, often repeated in the same district) at the pump or dip well of a private house, or, on a large or even vast scale in the source of public water works, and secondly there is the danger of breathing air which is fouled with effluvia from the same source of impurity.

6. Information as to the high degree in which those two dangers affect the public health in ordinary times, and as to the special importance which attaches to them at times when diarrhœal infection is likely to be introduced, has now for so many years been before the public that the improved systems of refuse removal and water supply by which those dangers are permanently obviated for large populations, and also the minor structural improvements by which separate households are secured against them ought long ago to have come into universal use.

So far, however, as this wiser course has not been adopted in any sanitary district, security must, as far as practicable, be sought in measures of a temporary and palliative kind. (*a*) Immediate searching examination of sources of water supply should be made in all cases where the source is in any degree open to the suspicion of impurity; and the water both from private and public sources should be examined. Where pollution is discovered, everything practicable should be done to prevent the pollution from continuing, or, if this object cannot be obtained, to prevent the water from being drunk. Cisterns should be cleansed and any connections of waste pipes with drains should be severed. (*b*) Simultaneously, there should be immediate thorough removal of every sort of house refuse and other filth which has accumulated in neglected places; future accumulations of the same sort should be prevented: attention should be given to all defects of house drains and sinks through which offensive smells are let into houses; thorough washing and lime washing of uncleanly premises, especially of such as are densely occupied, should be practised again and again.

7. It may fairly be believed that, in considerable parts of the country conditions favourable to the spread of cholera are now less abundant than at any former time; and in this connection, the gratifying fact deserves to be recorded that during recent years, enteric fever, the disease that in its method of extension bears the nearest resemblance to cholera, has continuously and notably declined in England. But it is certain that in many places such conditions are present as would, if cholera were introduced, assist in the spread of that disease. It is to be hoped that in all these

cases the local sanitary authorities will at once do everything that can be done to put their districts into a wholesome state. Measures of cleanliness taken beforehand are of far more importance for the protection of a district against cholera than removal or disinfection of filth after the disease has actually made its appearance.

8. It is important for the public very distinctly to remember that pains taken and costs incurred for the purposes to which this memorandum refers cannot in any event be regarded as wasted. The local conditions which would enable cholera, if imported, to spread its infection in this country, are conditions which, day by day, in the absence of cholera, create and spread other diseases; diseases which, being never absent from the country, are in the long run, far more destructive than cholera, and the sanitary improvements which would justify a sense of security against any apprehended importation of cholera, would to their extent, though cholera should never re-appear in England, give ample remunerative results in the prevention of other diseases.

GEORGE BUCHANAN,
Local Government Board, July 21, 1885. *Medical Officer of the Board.*

General Cholera Order.

To all Port Sanitary Authorities, except the Port Sanitary Authorities of the Port of London; to all Urban and Rural Sanitary Authorities, whose districts include or abut on any part of a customs port, which port is not within the jurisdiction of any Port Sanitary Authority; to all Officers of Customs; to all Medical Officers of Health of the Sanitary Authorities aforesaid; to all masters of ships; and to all others whom it may concern.

Whereas We, the Local Government Board, by an Order bearing date the 17th day of July, 1873, made certain rules and regulations with a view to the treatment of persons affected with cholera, and for preventing the spread of the disease; and whereas cholera is now[1] prevalent in certain parts of Egypt with which this country has communication, and it is expedient that in place of the rules and regulations made by the said Order, other rules and regulations as hereinafter contained should be made:

Now therefore We, the Local Government Board, do hereby rescind the said Order, except in so far as it may apply to any proceedings now pending, and We do, by this our Order, and in exercise of the power conferred on us by section 130 of the Public Health Act 1875, and every other power enabling us in this behalf, make the following rules and regulations, and declare that they shall be enforced and executed by the authorities hereinafter named:—

DEFINITIONS.

Article 1. In this Order—The term "ship" includes vessel or boat; the term "officer of customs" includes any person acting under the authority of the Commissioners of Customs; the term "master" includes the officer or person for the time being in charge or command of a ship; the term "cholera" includes choleraic diarrhœa; the term "Sanitary Authority" means every Port Sanitary Authority except the Port Sanitary Authority for the Port of London, and every Urban or Rural Sanitary Authority whose district includes or abuts on any part of a customs port, which port is not within the jurisdiction of a Port Sanitary Authority; the term "Medical Officer of Health" includes any duly qualified medical practitioner appointed by a Sanitary Authority to act in the execution of this Order.

For the purposes of this Order—

(1) So much of a customs port abutting on an Urban or Rural Sanitary District as is nearer to such district than to any other, and is not included within the jurisdiction of any Port Sanitary Authority, shall be deemed to be within such district.

(2) Every ship shall be deemed infected with cholera in which there is or has been during the voyage, or during the stay of such ship in a port in the course of such voyage, any case of cholera.

[1] 1883.

I. Regulations as to Detention by Officers of Customs.

Article 2. If any officer of customs, on the arrival of any ship, ascertain from the master of such ship or otherwise, or have reason to suspect, that the ship is infected with cholera, he shall detain such ship, and order the master forthwith to moor or anchor the same in such position as such officer of customs shall direct, and thereupon the master shall moor or anchor the ship accordingly.

Article 3. While such ship shall be so detained no person shall leave the same.

Article 4. Such detention by the officer of customs shall cease as soon as the ship has been duly visited and examined by the Medical Officer of Health; or if the ship shall, upon such examination, be found to be infected with cholera, as soon as the same shall be moored or anchored in pursuance of Article 10 of this Order. Provided that if the examination be not commenced within twelve hours after notice given as aforesaid, the ship shall, on the expiration of the twelve hours, be released from detention.

II. Regulations as to Sanitary Authorities.

Article 6. Every Port Sanitary Authority, except as aforesaid, and every other Sanitary Authority within whose district persons are likely to be landed from any ship coming foreign, shall as speedily as practicable, with the approval of the chief officer of customs of the port, fix some place within the jurisdiction or district of the Sanitary Authority where any ship may be moored or anchored, for the purpose of Article 10; and shall make provision for the reception of cholera patients and persons suffering from illness removed under Articles 13 and 14.

Article 7. The Sanitary Authority, on notice being given to them by an officer of customs, under this Order, shall forthwith cause the ship, in regard to which such notice shall have been given, to be visited and examined by their Medical Officer of Health for the purpose of ascertaining whether she is infected with cholera.

Article 8. The Medical Officer of Health, if he has reason to believe that any ship within the jurisdiction or district of a Sanitary Authority, whether examined by the officer of customs or not, is infected with cholera, shall, or if she have come from a place infected with cholera, may visit and examine such ship for the purpose of ascertaining whether she is so infected, and the master of such ship shall permit the same to be so visited and examined.

Article 9. If the Medical Officer of Health, making such examination as aforesaid (whether under Article 7 or 8), shall be of opinion that the ship is infected, he shall give a certificate in duplicate in the following form or to the like effect, and shall deliver one copy to the master and retain the other or transmit it to the Sanitary Authority.

Certificate.

―――――― day of ――――――――, 188 ,

―――――――― Sanitary Authority of ――――

I hereby certify that I have examined the ship ―――――――――― of ―――――――― now lying in the port of ――――――――――

(or detained at ――――――――――――), and that I find that she is infected with cholera.

――――――――――――

Medical Officer of Health (or medical practitioner appointed by the Sanitary Authority).

Article 10. The master of every ship so certified to be infected with cholera shall thereupon moor or anchor her at the place fixed for that purpose under Article 6, and she shall remain there until the requirements of this Order have been duly fulfilled.

Article 11. No person shall leave any such ship until the examination hereinafter mentioned shall have been made.

Article 12. The Medical Officer of Health shall, as soon as possible after any such ship has been certified to be infected with cholera, examine all persons on board the

same, and all persons who shall not be certified by him as hereafter mentioned shall be permitted to land immediately on their giving their names and the places of their destination.

Article 13. Every person certified by the Medical Officer of Health to be suffering from cholera, shall be dealt with under any regulations that may have been made by the Sanitary Authority under Section 125 of the Public Health Act 1875 ; or where no such regulations shall have been made shall be removed, if the condition of the patient admit of it, to some hospital or place previously appointed for that purpose by the said authority ; and no person so removed shall leave such hospital or place until the Medical Officer of Health shall have certified that such person is free from the said disease. If any person suffering from cholera cannot be removed the ship shall remain subject, for the purposes of this order, to the control of the Medical Officer of Health ; and the infected person shall not be removed from or leave the ship, except with the consent in writing of the Medical Officer of Health.

Article 14. Any person certified by the Medical Officer of Health to be suffering from any illness which such officer suspects may prove to be cholera, may either be detained on board the ship for any period not exceeding two days, or be taken to some hospital or other place previously appointed by the Sanitary Authority, and detained there for a like period, in order that it may be ascertained whether the illness is or is not cholera. Any such person who while so detained shall be certified by the Medical Officer of Health to be suffering from cholera shall be dealt with as provided by Article 13 of this Order.

Article 15. The Medical Officer of Health shall, in the case of every ship certified to be infected, give directions, and take such steps as appear to him necessary, for preventing the spread of infection, and the master of the said ship shall forthwith carry into execution such directions as shall be so given to him.

Article 16. In the event of any death from cholera taking place on board of such ship while so detained, the master shall, as directed by the Sanitary Authority or the Medical Officer of Health, either cause the dead body to be taken out to sea and committed to the deep, properly loaded to prevent its rising, or shall deliver it into the charge of the said authority for interment, and the authority shall thereupon have the same interred.

Article 17. The master shall cause any articles that may have been soiled with cholera discharges to be destroyed, and the clothing and bedding and other articles of personal use likely to retain infection which has been used by any person who may have suffered from cholera on board such ship, or who having left such ship shall have suffered from cholera during the stay of such ship in any port, to be disinfected or if necessary destroyed ; and if the master shall have neglected to do so before the ship arrives in port, he shall forthwith, or upon the direction of the Sanitary Authority or the Medical Officer of Health, cause the same to be disinfected or destroyed, as the case may require ; and if the said master neglect to comply with such direction within a reasonable time, the authority shall cause the same to be carried into execution.

Article 18. The master shall cause the ship to be disinfected, and every article therein, other than those last described, which may probably be infected with cholera, to be disinfected or destroyed, according to the directions of the Medical Officer of Health.

Given under the seal of office of the Local Government Board, this twelfth day of July in the year one thousand eight hundred and eighty-three.

CHARLES W. DILKE, *President.*
HUGH OWEN, *Secretary.*

NOTICE.—The Public Health Act 1875 provides by section 130, that any person wilfully neglecting or refusing to obey or carry out, or obstructing the execution of any regulation made under that section shall be liable to a penalty not exceeding fifty pounds.

Date of publication in the *London Gazette,* 13th July, 1883.

(400) *Order Prohibiting Importation of Rags.*

The Order at the time of cholera apprehension in 1885 against the importation of rags from Spain, was to the following effect :—

Article 2. From and after the date of this Order, and until the 1st day of November, 1885, no rags from Spain shall be delivered overside nor landed in any port or place in England or Wales.

Article 3. If any rags shall be delivered overside or landed in contravention of this Order, they shall, unless forthwith exported, be destroyed by the person having control over the same, with such precautions as may be directed by the Medical Officer of Health of the Sanitary Authority within whose jurisdiction or district the same may be found.

Article 4. All masters of vessels, consignees, and other persons having control of any rags prohibited under this Order from being delivered overside, except for the purpose of export, or landed, are required to obey these regulations.

Article 5. All officers of customs are empowered to prevent the delivery overside or landing of rags in contravention of this Order.

Article 6. It shall be the duty of the Sanitary Authority to take proceedings against masters of ships, consignees, or other persons having control over any rags who shall wilfully neglect or refuse to obey or carry out, or shall obstruct the execution of any of these regulations.

DIARRHŒA—ENGLISH CHOLERA.

Diarrhœa is a general disease, the leading symptom of which is frequent purging; at present it is not possible to differentiate between acute diarrhœa and English cholera, nor is it possible to definitely state whether two or more essentially different diseases are included under the term "diarrhœa," the latter name being as a matter of fact given to any disease attendant with frequent purgation, and for which there does not appear any local lesion or any specific fever such as typhoid to account for it.

(401) *Mortality and Sickness from Diarrhœa.*

The amount of illness from diarrhœa it is impossible to state, but Dr. Ballard[1] gives as the result of his Islington statistics that out of 272,409 cases of sickness treated in charitable institutions 16,479, or 60·5 per cent., were due to diarrhœa. The amount of sickness varies very much in different years, and also the mortality.

During the ten years 1861 to 1870, out of 4,794,500 deaths registered from all causes, 207,256 were ascribed to diarrhœa, and during the ten years 1871 to 1880 out of 5,178,311 deaths

[1] "Diarrhœa and Diphtheria," *Med. Officers' Supplement, Rep. Local Government Board*, 1887.

221,552 were ascribed to diarrhœa. This is equal to 43·2 per 1,000 of all deaths in the first period of ten years, and to 42·7 per 1,000 of all the deaths in the second period (Ballard).

Dr. Ballard suggests that this may not be all the mortality, but only that which is immediate; diarrhœa, like scarlatina, specially interferes with the kidney function, and hence it may lay the foundation of kidney diseases which may at a long period afterwards prove fatal.

(402) *Symptoms.*

Dr. Ballard summarizes briefly the symptoms as follows:—Diarrhœa, vomiting, convulsive phenomena, a bodily temperature at certain periods above, at other periods below what is normal, reduction in quantity or actual suppression of urine, embarrassed breathing, and where looked for commonly physical indications of pulmonary hyperæmia or inflammation, pallor of the surface of the body, loss of bulk and flesh, and exhaustion with its various well-known clinical features. Occasionally there is jaundice. In two of Dr. Ballard's cases there was a fugitive rash. The diarrhœa may be very slight, there is nothing characteristic about the stools, but as a rule they are at one stage or another of the malady horribly offensive. Convulsions Dr. Ballard views as the most important phenomena of the malady, and when convulsions occur late they indicate a uræmic condition of the blood. The temperature in its course is peculiar and much like that of cholera. At the commencement there appears to be some little febrile disturbance, but sooner or later in the cases about to become fatal, the temperature falls more or less below the normal range, being lower in the morning than in the evening, and even then it mostly fails to attain a normal standard. Towards the end of a fatal case the temperature is apt to rise.

(403) *Seasonal Influences.*

Dr. Ballard has carefully studied the effect of season. The malady he concludes is not only present among the population every year but in all seasons and at all times of every year; but not in all seasons and times alike.

For example, taking his Islington experience, and dividing the

year into thirteen periods of four weeks each, from the first to the twentieth week he considers a *pre-epidemic period*, the next five periods belong to the *epidemic period*, and the last three to the *post-epidemic period;* or the seasonal influence may be considered in quarters. Of the 15,478 Islington cases, in the first quarter there occurred 8·7 per cent. of all the cases, in the second 16·8 per cent., in the third 60·7 per cent., and in the fourth 13·8 per cent.

In yearly variations of prevalence by far the greatest occur in the "epidemic period." From eleven years of the Islington statistics, Ballard thinks that a higher prevalence than usual in the "post-epidemic period" may be connected with a deficiency of customary prevalence in the preceding "epidemic period," and he gives tables illustrative of this and other points both with regard to diarrhœa observed in Islington and diarrhœa observed in Redditch; finally concluding that the lateness or earliness of attainment of maximum prevalence in the "epidemic period" has more to do with the "post-epidemic" prevalence than the degree of prevalence in the "epidemic period" has to do with it.

In Buchan and Mitchell's paper[1] the general seasonal distribution of deaths is well brought out, and Ballard's conclusions are confirmatory. Buchan's diagram looks like a section of an Alpine mountain, the peak of culminating point being attained in the first week in August, the deaths rapidly running up from zero in May, through June and July to as rapidly diminish down to Ballard's post-epidemic period, but still a little above the average through October, November and December.

The most instructive part of Ballard's study on seasonal influences is that in which he traces the influence on the different ages. Taking the six years 1857 to 1862, 40·6 per 10,000 of all ages were known to be attacked in the pre-epidemic period, 230·5 in the epidemic, and 37·5 in the post-epidemic period. In the pre-epidemic period 135·2 per 10,000 of the age period under five, were attacked, and 26·0 of the population over five, hence the proportion was as 52 to 10 during the epidemic period, 816·4 per 10,000 under five, and 140·3 over five, that is in the proportion of 58 to 10; while during the post-epidemic period the relation is as 65 is to 10.

[1] *Journ. of the Scottish Met. Soc.*, July, 1875.

(404) *Predisposition.*

From Dr. Ballard's exhaustive inquiry it seems that contrary to general belief the healthiest children suffer most from diarrhœa; on the other hand, as might be expected, it is *most fatal* among weakly children. Presuming that diarrhœa is excited by a chemical poison like Vaughan's tyrotoxine, it may be argued that the healthiest children are the greatest feeders, and therefore would be likely to take a greater dose of the poison in milk or other substances; hence this fact may be scored on the side of the chemical theory.

(405) *Bacteriology of Diarrhœa.*

Dr. Tomkins of Leicester has investigated the micro-organisms found in the air of diarrhœal affected localities. Dr. Klein and others have investigated the bacteria found in the intestine and the discharges, but it cannot be said that any very definite result has yet been attained. Tomkins found a larger number of micro-organisms in affected areas than elsewhere. For instance, 6,000 colonies of bacteria per cubic metre within the area and 1,600 to 2,300 without the area, but he did not identify the various species nor investigate their pathogenic action. In the discharges Klein found the following:—

(*a*) A mobile spore-bearing bacillus which proved to be the bacillus amylobacter.

(*b*) A bacillus resembling bacterium termo.

(*c*) A thin non-mobile bacillus, in some examples containing two or four granules; it grows in clumps and corresponds to the bacillus of Escherlich.

(*d*) Various forms of micrococci differing from one another in size and arrangement; while some formed exquisite chains, others formed more or less sarcina-like groups, while still others were aggregated in clumps or zoogloea.

Careful microscopical examination of the tissues and blood of a number of cases of diarrhœa failed to discover any micro-organisms save in one case in which a bacillus was discovered strikingly like that described by Gaffky as the cause of typhoid fever. Dr. Klein is apparently not certain that it is identical; it grew in gelatin

more rapidly than Gaffky's bacillus, and had a greater resisting power to mercury perchloride; it was fatal to mice, and the *post-mortem* appearances were those of septicæmia.

(406) *General Results of Dr. Ballard's Inquiry.*

The general results of Dr. Ballard's inquiry is summed up in the following eighteen paragraphs:—

A.—General Conditions.

1. *Atmospheric Temperature.*—That a high atmospheric temperature conduces to a high diarrhœal mortality, and a low atmospheric temperature to a low diarrhœal mortality, is an established fact which no one can dispute. But my inquiry shows that the influence thus exerted is not a direct influence, excepting so far as it affects also infant mortality from all causes. It is not the main cause of the diarrhœal mortality. Its influence is very great, but is exerted indirectly.

2. *Temperature of the Earth.*— This is a far more important condition. I have made for London and many other towns in the kingdom a large number of charts, showing week by week for many years the earth temperature at a depth of one foot from the surface, and at a depth of four feet from the surface, each chart showing also the diarrhœal mortality of the corresponding weeks. The general result shown by these charts is as follows:—(*a*) The summer rise of diarrhœal mortality does not commence until the mean temperature recorded by the four-foot earth thermometer has attained somewhere about 56° F., no matter what may have been the temperature previously attained by the atmosphere or recorded by the one-foot earth thermometer. (*b*) The maximum diarrhœal mortality of the year is usually observed in the week in which the temperature recorded by the four-foot earth thermometer attains its mean weekly maximum. (*c*) The decline of the diarrhœal mortality is in this connection not less instructive, perhaps more so than its rise. It coincides with the decline of the temperature recorded by a four-foot earth thermometer, which temperature declines much more slowly than the atmospheric temperature, or than that recorded by the one-foot earth thermometer (so that the epidemic mortality

may continue, although declining), long after the last-mentioned temperatures have fallen greatly, and may extend some way into the fourth quarter of the year. I do not wish it to be inferred that the atmospheric temperature and the temperature of the more superficial layers of the earth exert no influence on diarrhœa. Their influence, however, is little, if at all, apparent until the temperature recorded by the four-foot earth thermometer has risen as stated as above. Then their influence is apparent, but it is a subsidiary one.

3. *Rainfall exerts an Influence on Diarrhœa,* but (so far as is apparent at present) not equally in all periods of the diarrhœal season. The diarrhœal mortality is greater in comparatively dry seasons and less in wet seasons, especially if the drought on the one hand, and rainfall on the other, be remarkably protracted and excessive. But here again the tendency of the inquiry has been to show that the influence exerted is not direct (*e.g.*, by a washing of the atmosphere, so to speak), but indirect, viz., by its effect mainly in preventing the rise and (probably to a less extent) in hastening the fall of the temperature of the earth.

4. *Air Movement.*—Wind and comparative calm affect the diarrhœal mortality. Other things being equal, calm in the diarrhœal season promotes it, and high winds tend to lessen it.

B.—Conditions of Locality.

5. *Elevation above Sea Level.*—This has apparently an influence on diarrhœal mortality, but not a very remarkable or powerful one. It is an influence which when we regard large areas is lost sight of in the midst of much more powerful influences, and is not perhaps to be distinctly seen until we compare among themselves the different parts of comparatively small areas. In such areas we may often see that the lower levels are more affected than the higher levels ; but even here it is not easy to estimate the extent of this influence on account of the disturbance of the result by other more potent influences. But even when most obvious, it has appeared to me that elevation is not an influence that bears specially upon diarrhœa ; it affects also, and to much the same extent, mortality from other causes. It seems, in short, to influence diarrhœal mortality only in so far as it affects infant mortality from all causes together.

6. *Soil.*—I think I am in a position to say that the influence of soil is a decided one; and that although it may be observed in respect to some other causes of mortality (and so is not altogether peculiar to diarrhœa), it is observable most distinctly in relation to that disease. (*a*) Where the dwelling-houses of a place have as their foundation solid rock, with little or no superincumbent loose material, the diarrhœal mortality is, notwithstanding many other unfavourable conditions and surroundings, low, and may indeed be altogether unnoticeable. Deep and wide and frequent fissuring of a rock in a town, or superficial alternations of rock with looser material, modify this immunity. (*b*) On the other hand a loose soil, permeable more or less freely by water and by air, is a soil on which diarrhœal mortality is apt to be high. So far as I can see at present, of all natural soils, sand is the most diarrhœal, other things being equal, unless I class with it surface mould to a considerable depth. Gravel (a very indefinite term, which has a different meaning in different places) varies in its relation to diarrhœal mortality in proportion as the loose element of it or the stony element and the size of the stones it contains vary. The more gravel approaches sand in its fineness, or to rock in its coarseness, its relation to diarrhœa appears to be greater or to be less. Dwellers on loose slabby rock, as commonly seen overlying solid rock, have more or less diarrhœa in proportion as the slabby material is in small pieces, and mixed with looser earthy matter, or in larger blocks with little intervening earth. Clay soils, other things being equal, do not appear to be in themselves among those soils specially favourable to high diarrhœal mortality; when they have seemed to be so, the connection has appeared to me to be otherwise explicable. A soil which is a mixture of clay, sand, and stones (commonly called a "marl") is apparently favourable or unfavourable to diarrhœal mortality in proportion as it is loose or permeable on the one hand, or plastic on the other. (*c*) The presence of much organic matter in any soil renders it distinctly more favourable to high diarrhœal mortality than it otherwise would be. Such organic matter (organic fouling), however, need not be specially of a fæcal or excremental nature to exert this influence, hence diarrhœal mortality is apt to be high where dwellings are built upon made ground, the refuse of towns, or upon the site of market gardens; or where the earth beneath and about

dwellings is polluted by neighbouring collections of liquid filth in cesspits, or where sewage has soaked into it from imperfect drains and sewers, or from the surface of the ground. It is the opportunities for the collection of organic filth in the fissures of certain kinds of rock that seem to impart to these rocks, where towns are built upon them, a diarrhœal character.

(*d*) *Moisture or Dryness of a Soil.*—Excessive wetness and complete dryness of soil appear to be both unfavourable to diarrhœa. A degree of moisture specially favourable is an amount of habitual dampness which is decided although not sufficient to preclude the free admission of air between the constituent physical elements of the soil. Such a degree of dampness occurs when in the diarrhœal seasons the sub-soil water stands sufficiently near to the surface to maintain by capillary attraction the dampness brought about by previously greater nearness of the water to the surface; or when the soil, as in the case of marls, contains sufficient of the clayey element to imprison enough of the water saturating it some time previously. It is scarcely necessary to add that the requisite degree of dampness may be produced not only from a source below but from a surface source—for instance, it may be the result of a previous flood or of watery matter habitually soaking in from the surface about houses, or from leakages of such conduits as sewers or drains.

7. *Density of Population.*—Aggregation favours, dispersion over areas disfavours, diarrhœal mortality. There is nothing new in this; it is (together with the influence of temperature) the lesson annually repeated to us by the Registrar-General who every year indicates the fact that the diarrhœal mortality of towns much exceeds that of non-oppidan parts of the country, and that the diarrhœal mortality of large towns on the whole exceeds that of small towns. The same general lesson is taught by the comparison in particular towns of different parts of the same town, such as I have instituted in the course of this inquiry. But it is to be observed that the influence of aggregation of population is noticed also in respect of infant mortality from other causes: it is not limited to diarrhœal mortality, although (as shown in the provisional table) it appears most marked in the case of diarrhœa. Moreover, it is to be kept in mind that the parts of towns most densely populated are customarily the parts where the inhabitants are of the lowest

social grade, and where other conditions favourable to diarrhœal mortality are most abundantly operative. The influence of density of population on the prevalence of diarrhœa is commonly much less direct than in the case of such diseases as measles and scarlatina, although, as will be seen later on, the malady does on occasion spread from person to person.

8. *Density of Buildings* (whether dwelling-houses or other on area).—This is a different thing from population on area, as may be seen in almost every factory town, although, very commonly, the two conditions are combined. My inquiry tends to show that in a town, crowding of buildings, of whatever sort, in such a way as to cover area more or less closely with buildings, promotes diarrhœal mortality. This condition is seen in operation, for instance, most distinctly in parts of factory towns where buildings other than dwelling houses occupy much of the space, and where, consequently, the density of resident population on the area is not so great as it would be if the same space were covered wholly with dwelling houses. It is probable that this difference of density of buildings upon area is one of the circumstances which have to do with the difference of diarrhœal mortality between large and small towns.

9. *Restriction of and Impediments to the Free Circulation of Air Promote Diarrhœal Mortality* (*a*, about dwellings).—One cause of restriction and impediment lies in the condition last mentioned: this is most obvious where small dwellings are shut in among large and tall buildings, as in many courts and narrow streets of factory towns. Such causes also seem in operation where streets are built in such a direction or are so arranged (*e.g.*, like the mortar between bricks in a wall) as that they cannot be swept by the prevalent winds of the diarrhœal season ; or where the space at the rear of houses in a street, or between neighbouring streets, similarly cannot be swept by currents of air, *e.g.*, when the space between the rear of the houses is narrow and the ends of such space are obstructed by the buildings of a cross street or any other way. Very long, narrow streets, especially under the above-mentioned circumstances, are apt to present an excessive diarrhœal mortality. Openly built towns which from their surface configuration are so arranged that impediments to the circulation of air are comparatively trifling, have, as a rule, less diarrhœal mortality than those

in which impediments abound, other things being equal. (*b* within dwellings): The dwellings in which the free passage of air through them is most effectually prevented are those which are built "back to back." Taking these then as criteria, it may suffice to say, that the results of the Boards' inquiry into the mortality from diarrhœa and other causes in dwelling-houses of this sort are to the following effect, viz., that the absence of free domestic ventilation increases very greatly and very obviously the mortality from diarrhœa, and this very much more than it increases the mortality from all causes put together, more indeed than it does the mortality from the seven principal "zymotics" put together, and very much more than it affects the mortality from all causes, except these seven "zymotics."

10. *Domestic Darkness and general Dirtiness of Dwellings are conducive to Diarrhœal Mortality.*—Dirtiness with bad ventilation constitutes a condition known as "fustiness." It is a common-place condition in the crowded and poor parts of towns, and it is very much in the parts where these conditions prevail that the diarrhœal mortality is highest. But these conditions are so associated with other conditions conducive to the same result that I cannot at the present time define the extent of the influence of this special cause apart from them. The fact, however, is notorious. I am satisfied, from my own observations, that among the same class of people, the diarrhœal mortality is greater in proportion as general fustiness prevails in their dwellings. Darkness of dwellings is rarely associated with cleanliness or satisfactory ventilation. The influence of "fustiness" and its frequent concomitant darkness, is, I think, more obvious in respect of diarrhœa than in respect to the mortality from other causes.

11. *Sewer or Cesspool Emanations*, especially in a concentrated form, and suddenly let loose, may occasion attacks of fatal diarrhœa. Emanations of this sort, I think I have reason to believe, are of themselves capable of occasioning a diarrhœal epidemic even in a non-diarrhœal season of the year, and hence in diarrhœal seasons such emanations may well be believed to have an influence on epidemic diarrhœal mortality. Unusual diarrhœal mortality may, however, from time to time be observable in localities where there are no sewers to emit foul air, and where there is no reason for believing that cesspit emanations have been previously

unusual in amount, or have gained access to dwellings with unusual readiness.

12. *Atmospheric fouling from mere Coal Smoke or from the Gaseous Emanations from Chemical Works or of Chemical Refuse* appears to be inoperative, at any rate in the neighbourhoods habitually exposed to them, excepting so far as such atmospheric fouling may lower the general standard of infant health.

13. *Filthy Accumulations of Domestic Refuse in Privies, Ashpits, Dustbins.*—Comprising, as these do, an abundance of decomposing organic material, animal and vegetable, such accumulations promote, wherever they exist, diarrhœal mortality; especially they do so where free movement of air is impeded, and the atmospheric fouling, due to them is consequently concentrated. Fixed receptacles of filth may remain dangerous, even when emptied, on account of the encrusted state of their walls.

14. *Undefined Polluted Condition of Drinking Water* has from time to time appeared to give rise to epidemic diarrhœa, and this irrespective of the season of the year; but, so far as I have been able to ascertain, water-pollution has little or nothing to do in the way of direct causation with the diarrhœal mortality that occurs annually in this country in the summer.

C.—Conditions Relating to the Population.

15. *Social Position.*—It is notorious, and especially so among medical officers of health that the diarrhœal mortality of towns is very disproportionately distributed among the several social classes of the population, being comparatively small among the well-to-do portion of the community, and comparatively very great among families of the lower social grade. The more closely this general belief is looked into, the more confirmation it gains. Dr. Grimshaw's tables, in his paper on "Class Mortality Statistics" (*British Medical Journal*, August 13, 1887), give statistical evidence in this direction; but a careful study of Dr. Grimshaw's figures indicates that this condition influences the mortality from all other causes even to a greater extent than it does diarrhœal mortality alone; but although I have thought it desirable to advert to this consideration, it must not be forgotten how much this term "social position" involves when we compare the well-to-do with the poorer classes of the community, and each

with an intermediate class, both as respects the localities in which they severally dwell and the circumstances under which they live.

16. *Food.*—Although there is, I think, ground for the popular notions which associate epidemic diarrhœa with the consumption of articles of diet, the almost equally common notion that such diarrhœa arises from indigestibility of food or from faulty digestion on the part of the consumer of it is not, I am disposed to believe, so well founded; rather I am inclined to think of epidemic diarrhœa due to food arising through some extraneous substance in the food, which substance is by itself an efficient cause of the malady.

(*a*) As regards the influence of the mode of feeding of young infants, the incidence of diarrhœal mortality upon infants fed, on the one hand, exclusively on the breast, and, on the other hand, partially or entirely on other kinds of food, is, of special interest. The general conclusions arrived at by medical men who have studied the matter, and by medical officers of health who have adduced statistics in support of their opinions thereon, are generally to the effect that infants fed from the breast are remarkably exempt from diarrhœa as compared with infants that have been fed otherwise; and that feeding from the bottle had been principally concerned in the fatal diarrhœa of infants. But my difficulty about accepting these conclusions in their entirety has hitherto been absence of data as to the proportion of healthy children fed in these different ways. In this difficulty, Dr. Hope, the assistant medical officer of health for Liverpool, has come to my assistance, and has made some comparative statistical inquiries among infants in that city who were healthy, and among others who had died of diarrhœa in the summer season, and the general result of his inquiry, so far as I have at present worked upon his tables, is this: First, that infants fed solely from the breast are remarkably exempt from fatal diarrhœa, even among the low-class Irish, the degree of exemption being exactly the same among the Irish as among the English and other races in this city; second, that infants fed in whatever way with artificial food, to the exclusion of breast milk, are those which suffer most heavily from fatal diarrhœa; thirdly, that children fed partly at the breast and partly from other kinds of food suffer to a considerable extent from fatal

diarrhœa, but very much less than those which are brought up altogether by hand; fourthly, as respects the use of the bottle, it is decidedly more dangerous than artificial feeding without the use of the bottle.

(*b*) It is to be inferred generally, from observations which I have made, that the circumstances of food-keeping, of its exposure to telluric emanations (*e.g.*, as in underground cellars), or to emanations from accumulations of domestic filth (*e.g.*, when kept in pantries, &c.), to which such emanations have more or less free access, tends to render it liable to produce diarrhœa, especially where the storing place for food is dark, and is not exposed to currents of air.

17. *Maternal Neglect and Carelessness in Infant Management.*—In estimating (apart from other considerations already mentioned) the influences of this element of causation, I adopt as a criterion the prevalence of fatal diarrhœa among infants who are illegitimate as compared with its prevalence among the legitimate. The collective experience of three places—Salford, Great Yarmouth, and Scarborough—is, for all practical purposes, to this effect, viz.: First, that the infants most liable to be neglected, viz., those which are illegitimate, suffer exceptionally from all causes of infant mortality, but from diarrhœal mortality rather more than from other causes of death. Secondly, that in years of high epidemicity this greater tendency on the part of the illegitimate infants to suffer from diarrhœal mortality is lost sight of. Thirdly, that in years of low epidemicity the tendency above mentioned is most obvious, *i.e.*, the presumably less potent or less abundant specific cause (in such years) operates fatally and more easily on the illegitimate than on the better-cared-for class of infants. Fourthly, in a highly epidemic year this class of infants seems to suffer earlier than the class of infants better cared for.

18. *Occupation of Females from Home.*—This which has often been assigned by medical officers of health and others as a fruitful cause of infantile fatal diarrhœa resolves itself mainly into the question of maternal neglect, with the substitution more or less of artificial feeding for feeding at the breast, matters which have been dealt with in preceding paragraphs.

Having regard to the broad facts already indicated, and to

others which have yet to be exhibited by me, a working hypothesis or provisional explanation that would best accord with the totality of the evidence in my possession, bearing on the production of epidemic diarrhœa may be stated as follows :—

That the essential cause of diarrhœa resides ordinarily in the superficial layers of the earth where it is intimately associated with the life processes of some micro-organism not yet detected, captured, or isolated.

That the vital manifestations of such organism are dependent among other things, perhaps principally, upon conditions of season and on the presence of dead organic matter which is its pabulum.

That on occasion such micro-organism is capable of getting abroad, from its primary habitat the earth, and having become air-borne, obtains opportunity for fastening on non-living organic material, and of using such organic material both as nidus and as pabulum, in undergoing various phases of its life history.

That in food, inside as well as outside of the human body, such micro-organism finds, especially at certain seasons, nidus and pabulum convenient for its development, multiplication, or evolution.

That from food as also from the contained organic matter of particular soils, such micro-organism can manufacture by the chemical changes wrought therein through certain of its life processes, a substance which is a virulent chemical poison ; and that this chemical substance is, in the human body, the material cause of epidemic diarrhœa.

It will be observed that this provisional hypothesis is sufficiently elastic to include as a common cause of diarrhœa chemical products of bacterial life manufactured indifferently within or outside the human body.

Elasticity to this extent of a provisional hypothesis has been necessary for the reason that in the present state of our knowledge certain cases and groups of cases of diarrhœa not distinguishable from epidemic summer diarrhœa, have now and again been found to possess the faculty of being directly communicable from person to person.

It will be obvious that in the stools of such infective cases of diarrhœa the hypothetical organism causative of the malady may be looked for with good hope of success.

(407) *Practical Action to be Taken as Preventive of Diarrhœa.*

The practical action a Medical Officer of Health should take in regard to diarrhœa is, in the first place, to ascertain from mortality statistics and from any registers of sickness which are accessible the localities and houses in which year by year diarrhœa mostly prevails. He will find that as a rule the same houses are attacked with remarkable regularity; to these houses he will direct his attention, and study drainage, water-supply and their general sanitary conditions. One of the main objects of his research will be the conditions *under which food is stored.* In the homes of artisans and the poorer class in cities, those who can afford but two or three rooms, it is useless to talk of a "pantry," the household food is put into a cupboard or simply exposed in the dwelling, or it may be sleeping room. In such cases contamination of the food is almost impossible to prevent, but much may be hoped from the people themselves. If the people of this class had the necessary knowledge, they would understand that it is unwise to buy in any stock of food of a fermentable character, such as sausages, meat, or milk; food only just sufficient for the day should be bought, the milk be at once boiled, and no food eaten without thorough cooking. In the better class of houses, besides the general details of drainage, ventilation, &c., special attention should be paid to the situation of the pantry, and it should be particularly noted whether the incoming air passes over any drain or foul collection of matter. The writer has known the air pouring into pantries and safes where food is kept derived from defective water closets, from close yards trapped with imperfect bell traps and from similar places. In some districts medical officers of health have distributed leaflets containing instructions to the people how to preserve their children and themselves from diarrhœa. They are told not to give their children any milk but that which has been boiled, to keep their food in a proper place, mothers never to suckle their children without first cleansing well the nipple, and when diarrhœa actually occurs to thoroughly disinfect the excreta. There can be little doubt that a certain proportion of the people to whom these leaflets are delivered, read and profit by the instruction.

SECTION IX.

ISOLATION HOSPITALS.

CHAPTER XXXIII.

THE PRINCIPLES OF CONSTRUCTION OF ISOLATION HOSPITALS.

(408) *Infectious Hospitals.*

A LARGE amount of experience, both as regards the construction and administration of infectious hospitals, has been acquired during the last thirty years, and the results of this experience are easily accessible, thanks to the reports of Dr. Bristowe and Mr. Holmes in 1863, to the inquiry of Dr. Thorne Thorne in 1881, and to the work of the Asylums Board.

In this chapter the chief material used is Dr. Thorne Thorne's very able summary:—

The first principle to be laid down is the absolute necessity of buildings set apart for small-pox, scarlet and other infectious fevers. A sanitary authority, not providing facilities for isolation, has failed to fulfil one of the great purposes for which it was instituted.

The second principle is that the construction of such hospitals, is best carried out with deliberation in non-epidemic times, experience having demonstrated that those which have been hastily run up to meet sudden emergency, have provided accommodation of a most indifferent kind, have failed to meet the permanent wants of a district, and the cost has been in relation to usefulness large.

The third principle is that small-pox hospitals should be at least a mile from inhabited dwellings.

(409) *Site.*

It is seldom that there is a free untrammelled choice of site, but the considerations most weighty are (1) moderate elevation; (2)

ample and pure water supply; (3) facilities for drainage; and (4) a dry healthy soil. The authorities generally also agree that it is desirable the opposite side windows of the ward pavilions should face respectively east by south and west by north.

(410) *Hospital Construction.*

Hospitals for infectious diseases are composed of (1) an administrative block; (2) wards; (3) outbuildings, such as wash-house, disinfecting chamber, mortuary.

(1) *Administrative Block.*—This should always be constructed in excess of the requirements of the permanent wall buildings—it is by far the most important block. It would indeed be practical in rural districts to rely wholly upon a good permanent administrative block and four small permanent wards, extending the accommodation as required by means of tents or huts. The general construction of the administrative block should of course follow the rules and regulations governing the erection of modern dwelling houses generally; it is, however, more important than even in the above to shut out the ground air by means of concrete or asphalt. Most of the administrative blocks have consisted of only one story, but considering that nurses have to take some part of their rest in the day, it is preferable to have two stories; sleeping rooms on the first floor being more quiet. The smallest administrative blocks contain the following:—kitchen; scullery; pantry, or larder; medical officer's room and dispensary combined; bedrooms; one or more water-closets. The larger administrative blocks contain provision for the accommodation of a resident medical officer, a mess room for the nurses and staff, bathrooms, &c. The administrative blocks should be some little distance from the ward buildings, communicating with them by means of a covered way—this covered way is best open at the sides.

(411) *The Wards.*

The permanent wards should be constructed of brick or stone; at Weymouth concrete has been used advantageously. Corrugated iron hospitals lined with matchwood and wooden huts have all been failures as regards temperature and comfort.

"At Nottingham, where the two layers of wood forming the walls are six inches apart, the interspace being filled with sawdust,

it was on one occasion found impossible even when large fires were maintained night and day to raise the temperature near some of the beds beyond 32° F. In the Alcester rural district, where there is a very similar building, the temperature was found in the winter of 1880-81, and under the same conditions, to fall to 38° F."

If attempts be made to remedy these inherent defects then the initial cost is brought up to that of stone or brick buildings, while the maintenance is greater and the durability less.

The wards usually consist of a single story, but there may be reasons, such as limited area of site, to prefer two stories rather than encroach upon the airing ground.

There must be ample space for the whole of the wards and buildings, the number of patients per acre should not be more than twenty. The floor space per patient should be 144 square feet as a minimum, the cubic space at least 2,000 cubic feet, the window surface should be in the proportion of 1 square foot to about every 70 cubic feet. Excessive window surface is to be avoided.

Dr. Angus Smith, F.R.S., made some careful experiments as to the ventilation of the Children's Hospital at Pendlebury, which has window surface in the proportion of 1 square foot for every 35 cubic feet, but it was found that owing to this extent of window surface the ward air could not be kept pure and at the same time equably warm.

If according to these principles a ward for four patients be designed, the floor might be 24 feet square, and 14 high, which will give 2,000 cubic feet per bed and 144 square feet of floor space per bed, the windows 4 in number may be 3×5 feet, giving 1 square foot to every 88 cubic feet. The windows should serve the purpose of both lighting and ventilation, hence the double hung sliding sash window is the best type. The position of the windows should be opposite each other, one being in the centre of each side wall, the others near the angles beyond each end bed. The walls should be lined with Parian cement or glazed bricks, so that they can be readily washed and disinfected. All architraves, cornices and ledges where dust could collect must be avoided.

(412) *Ventilation.*

However efficient windows of the class mentioned may be as ventilators, in all cases Tobin's tubes should also be placed at the

angles of the walls; and experience has shown that in order to change quickly and completely the air of the wards at least twice daily, openings must be made at the floor level—these openings should be capable of being closed by a sliding door—two will be enough on opposite sides, but they should be of considerable length, 4 feet by 6 inches.

The superior results of mechanical ventilation in the case of schools has been referred to at page 85, and the same remarks apply to hospitals.

(413) *Warming.*

A small ward like the one suggested may be warmed by an open fire-place—Green's grate is a good one for the purpose, the grate may be at either end. A larger ward would probably have to be heated by pipes or by centrally placed stoves.

(414) *Closets.*

A closet should be placed at the end of the ward, a small lobby having cross ventilation being interposed. If a water-closet be used it should be provided with an automatic disinfecting apparatus discharging either 90 per cent. phenol into the pan, or a 2 per cent. solution of corrosive sublimate.[1] It would be still better if the dry system were adopted for the excreta, using saw-dust which has been saturated with petroleum and burning it in a special crematory furnace.

(415) *Sinks—Drainage.*

The ward must have a sink to throw slops down, and this necessitates a drain. No evil is recorded to have resulted from connecting fever hospitals with the public sewer system, but if there are no sewers available the ward and other buildings can drain into impervious cesspits of proper construction, the drainage of course being trapped, and provided with ventilating shaft and disconnecting chamber. In some places where the local conditions are favourable sub-soil irrigation has been successfully employed.

[1] Dissolved by the aid of ammonium chloride.

(416) *Furniture.*

The four bedsteads must be of iron, and have wire-coil or wire-spring mattresses—so as to form a bedstead and mattress in one, and then horse-hair beds placed upon them; the latter easily admit of disinfection in a hot-air apparatus, and the wire-coil mattresses can be washed and cleaned *in situ*. There may be a few rugs on the floor, or pieces of carpet, for these are easily cleaned and freed from infection.

A laundry is an essential part of the hospital, and should form an annex to the administrative block.

(417) *Disposal of the Dead.*

The bodies of patients dying of small-pox as well as those dying of typhus, it is certain are highly infectious; but there is not an equal amount of evidence as to infection from scarlet fever; nevertheless it is safest to treat the corpse in all cases as likely to be injurious to the living, save in the presence of strong disinfectants. Cotton wool steeped in a 5 per cent. alcoholic solution of corrosive sublimate should be packed carefully into the mouth, the nostrils, ears, and other apertures of the body, the whole surface of the body should then be sponged with a saturated aqueous solution of the same salt, and finally packed in sawdust mixed with sanitas powder. In this way a fairly perfect disinfectant combined with concealment of foul odours is attained.

The mortuary proper, that is the space within which the bodies themselves are placed, should be well ventilated. For this purpose there should be oblong openings close to the floor covered with wire gauze, and swing windows also protected by gauze to prevent the entrance of flies, and by blinds to shade off direct sunlight.

(418) *The Local Government Board Hospital Plans.*

Plans have been issued by the medical department of the Local Government Board,[1] as a guide to local authorities in the construction of hospitals. The first plan is that of the smallest hospital, simply consisting of a cottage-like building to hold two patients

[1] *Seventeenth Annual Report (Supplement)*, p. 199.

of each sex. A second plan is that of a larger but still small hospital for six patients, with separation of sex, and also of one infectious disease from another. The building is a long narrow one, and should face north and south if the site allows. The men's wards have a verandah on one aspect, the women's on the other. The roof of the verandah is so planned that it does not run close to the eaves, but to a point which marks the division of the window into sash and hopper. The wards and the nurses' rooms open direct on to the verandah; this is surely objectionable, and the addition here of a lobby would be an improvement.

The third and fourth plans are here reproduced, the one being a plan for a pavilion of twelve beds, the other being a plan of a block for ten beds. In all these plans provision is made for 144 square feet of floor space, 12 linear space of wall space, and at least 2,000 cubic feet of air space per bed. The block plan would be improved by the addition of lobbies to the doors opening into the verandah, and one or two windows for the purpose of better ventilation in the long blank wall of the end wards. The absence of a proper bath-room also invites criticism. Nor in cold weather will it be very comfortable for patients well enough to move about to have to brave the cold draught in the verandah to use the closet; but these details evidently admit of remedy.

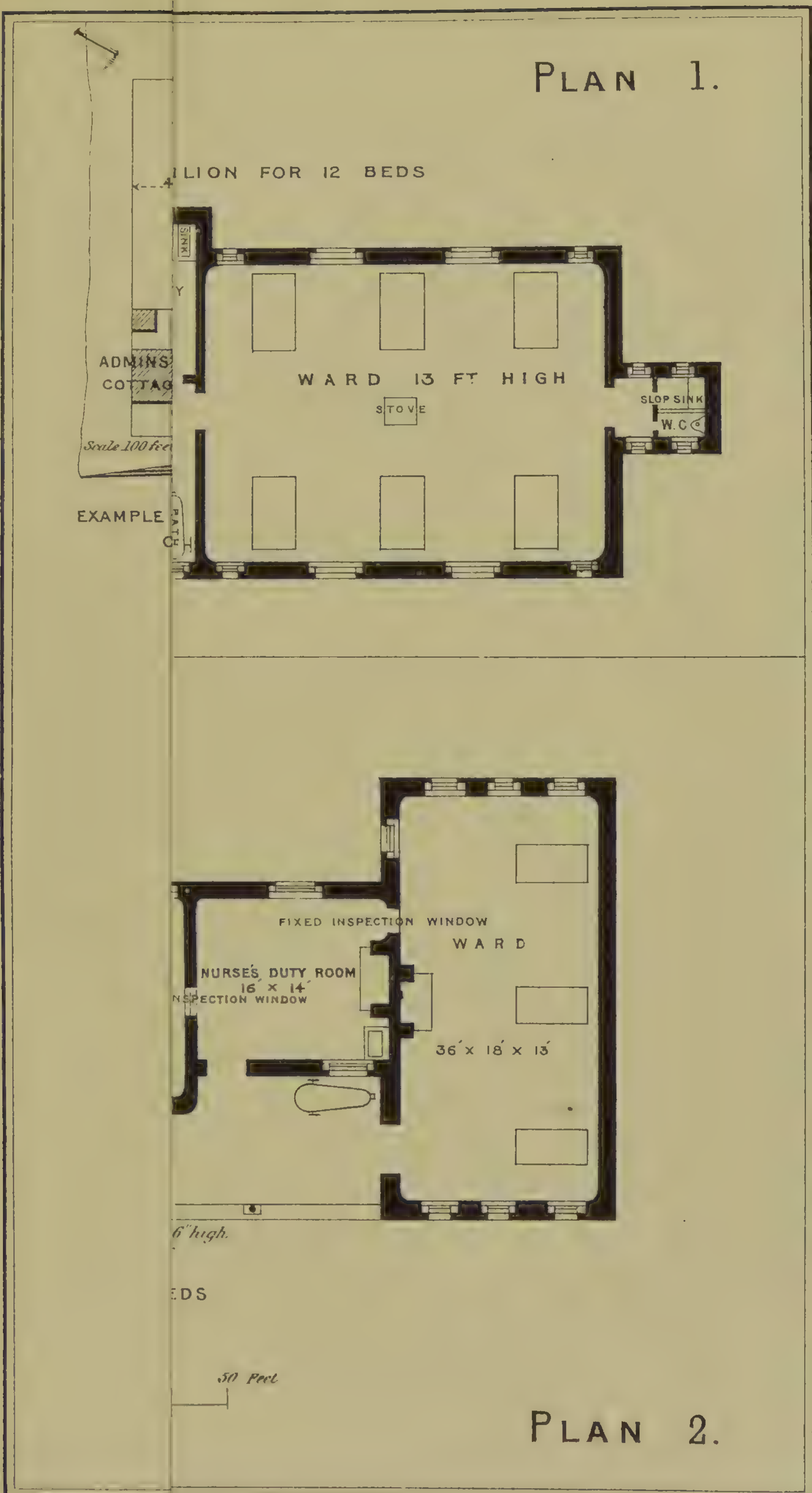
It is, lastly, to be mentioned that the four plans all presume that the boundary fence is at least 40 feet from the hospital buildings.

(419) *The Superintendence and Management of Hospitals.*

The principles of the management of infectious hospitals are, so far as daily routine and discipline goes, no different from those of other institutions, but there are special points to be considered with regard to preventing the spread of infection by the nurses, attendants, patients, visitors, and their friends.

The following rules,[1] adopted by the Asylums Board, are all that in practice will be found to work; if rules are too stringent they fail from impracticability. The Asylum Board rules are good

[1] These rules are extracted from the *Manual of Regulations* of the Asylums Board. Of course the rules selected are only those which are in one way or the other connected with infection.



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common-sense precautions, and may be well taken as a model, little details being altered to suit local requirements:—

(420) *Duties of Nurses.*

To see that the clothing found upon each patient is sent to the disinfecting room.

To see that all soiled and dirty linen be set aside, and sent to the patients' laundry at the earliest possible opportunity.

In every case of death to superintend the washing, laying out, and shrouding of the corpse, and to give orders for its removal to the mortuary.

To be careful that all dust, rags, and combustible refuse of any kind from the wards are burnt, and not thrown into the dusthole.

(421) *Duties of the Laundry Superintendent.*

To see that all articles are placed in the disinfecting tanks separately, and not in bundles.

(422) *Duties of the Gate Porter.*

To keep the gates, and to prevent any person not being a principal officer of the hospital, or a visitor to a principal officer, or an officer of the Board of Management, an inspector of the Local Government Board, a minister of religion, or any other person authorised by law, or by the Local Government Board, or Board of Management, from entering into or going out of the hospital without the written leave of the medical superintendent, or of the steward or matron acting under his authority.

To keep a book to be supplied by the Board of Management, in which he shall enter the name of every officer, and the name and business of every other person who shall go into or out of the hospital, together with the time when such officer shall go in or out.

Not to allow any male or female subordinate officer to pass the gates in the uniform or dress worn in the hospital.

To understand that unless a patient's name is entered in the visiting book as being in a dangerous condition, he or she is progressing favourably.

The contractors are not to employ in the delivery of stores at the hospitals any person who is not certified by the medical superintendent as having been efficiently vaccinated or revaccinated. The gate porter will see that the conditions of this resolution are complied with.

(423) *General Regulations.*

No member of the staff is permitted to leave the hospital premises without having first entirely changed his or her wearing apparel.

Nurses and those attending patients are to be permitted to leave the ward half an hour before leave commences, for the purpose of entirely changing their wearing apparel, and if possible taking a bath.

(424) *Regulations as to Condition of Patients.*

Upon the admission of a patient, a letter with a copy of the regulations is to be sent to the nearest known relative or friend, setting forth the state of the patient; should any serious change for the worse take place, a letter is to be sent daily to the relative or friend, stating how the patient is progressing, which letter is to be continued until the patient is in such a condition as to render further communications unnecessary; but should the patient become dangerously ill, notice is to be sent by the steward of the hospital to the nearest known relative or intimate friend, with an intimation that the patient may be visited; and the steward may, at the discretion of the medical superintendent, and subject to the approval of the Committee of Management, make arrangements for the conveyance of the visitor to and from the hospital.

Applications for information as to the condition of patients must be made in writing to the medical superintendent, who will reply by return of post. It is very undesirable that friends of patients should personally make inquiries at the hospital.

(425) *Visiting.*

The visiting of patients is to be limited to the nearest relatives and intimate friends of patients dangerously ill. One visit only

will be allowed daily to each patient. Visits, which will not be permitted without the permission of the medical superintendent, are, as a rule, to be limited in duration to a quarter of an hour. In urgent and special cases, however, the medical superintendent is empowered to increase the number of visitors to two, and to extend the duration of the visit.

Visitors are warned that they run great risk in entering the hospitals. They are advised not to go into the wards of the small-pox hospitals without having been properly revaccinated, and if they reside where the case visited occurred, are earnestly requested to urge the remainder of the occupiers of such house to call at once on the public vaccinator (whose address can be obtained from any of the parish officers) for the purpose of being vaccinated.

Visitors are further advised not to enter the wards of any of the hospitals when in a weak state of health, or in an exhausted condition, but to partake of a good meal before entering the hospitals. They will be required when in the wards to carefully avoid touching the patient, or exposing themselves to his breath, or to the emanations from his skin, and will not be permitted to sit on the bed or handle the bedclothes, but will be allowed to sit on a chair by the bedside at some little distance from the patient.

Visitors will also be required to wear a wrapper (to be provided by the Board) to cover their dress when in the wards, and to wash their hands and face with carbolic soap and water before leaving the hospital, or to use such other mode of disinfection as may be directed by the medical superintendent.

Visitors are strongly urged not to enter any omnibus, tram car, or other public conveyance, immediately after leaving the hospital.

SECTION X.

FOOD.—DIET.

CHAPTER XXXIV.

THE PRINCIPLES OF DIET.

FOODS are scientifically divided into :—1. Water. 2. Meaty or albuminous. 3. Starches or Carbohydrates. 4. Fats. 5. Mineral matters.

(426) *Water in Food.*

This varies much; some succulent fruits contain quite 90 per cent. of water; green vegetables from 60 to 90 per cent. Meat about 75 per cent. Artificial baked products such as rusks contain the least water.

Hence it is not absolutely necessary to replace the fluids of the body by water *per se*, there are at the present time in England a few persons who affirm that they drink neither tea, coffee, soup, fermented nor unfermented liquids. They obtain the necessary water entirely from fruits such as oranges and vegetables, such as water melons, and the like.

The amount of water, taken as water or in the shape of liquids, such as tea, coffee, soup, or beer, varies much according to custom, to climate, and to exercise; in our own climate two and a half pints daily may be put as a sufficient quantity; the water in the solid food will amount to about two pints, making a daily total of four and a half pints.

Water is entitled to the name of food, for it does not act merely as a dilutent of the secretions, or a solvent assisting excretion, but it helps to build new tissue and to repair old. When deprived of food and water it is the latter want that is felt the soonest; if water

If nitrogen is cut off, the store are drawn upon, but when a normal diet is again taken, that which has been diminished is replaced by marked storage or retention. Any sudden and severe exertion draws heavily upon the nitrogen.

For example, in one of Mr. North's[1] numerous experiments in which he walked thirty-two miles in eight-and-a-quarter hours, the nitrogen at once rose far above the daily excretion, and continued for several days to be above the normal. Notwithstanding that with the exception of bodily labour or rest, the conditions of food (intake), as to both quantity and quality were identical; the output of total nitrogen, sulphates and phosphates may be traced by means of the diagram, the thirty-two miles walked on the 28th is indicated by a vertical line.

(429) *Quantity of Nitrogen Required.*

The quantity of nitrogen required in the form of vegetable or animal albumen, is not known with the greatest accuracy; but this is certain, that the quantity has been a little overstated by writers on the subject. Mr. North, a man weighing about 131 lbs., and living upon an experimental diet, found nitrogen accumulation to take place when the daily supply did not exceed 17·6 grms. (284·4 grains), hence the limit for this particular individual must be below 17·6 grms.

In experiments made by the author, in which a man weighing 122 lbs. lived on whole meal products and distilled water for twenty-eight days, there were indications that 175 grains of nitrogen, had the carbon been increased, would have maintained the bodily weight; the diet sufficient according to the late Dr. Lewis[2] to maintain Hindoos, of the average weight of 110 lbs. contains 207 grains of nitrogen. Indoor operatives in England support life and body weight on a diet which averages about 179 grains of nitrogen. From all the facts I gather that the nitrogenous limit is something near 1·78 grain per pound of body weight (·25 gram per kilo); in other words an adult of the standard weight of 150 lbs. would require 267 grains. This, be it noted, is a minimum, but

[1] *Proceedings of the Royal Society*, No. 241, 1885.
[2] *Proceedings of the Royal Society*, vol. xlv. 509.

when the inquiry is what is a safe average for use in calculating diets, the answer is something near 290 grains; Moleschott put it higher, viz., 316 grains.

(430) *Carbohydrates.*

The type of the carbohydrates is sugar or starch, and the composition of both sugar and starch is simply that of a union of carbon and water; hence the name "carbohydrate." The molecular weights of sugar and starch are however not identical. The chemical formula for starch being $C_6H_{10}O_5$, or six atoms of carbon united intimately with five atoms of water (H_2O); the chemical formula for cane sugar is $C_{12}H_{22}O_{11}$, or twelve atoms of carbon united with eleven atoms of water. It follows that the percentage composition of both when carefully dried is the same. Thus :—

Carbon		. . . .	44·45 per cent.
Hydrogen	6·06	Water	55·55 ,, ,,
Oxygen	49·49		

The four chief carbohydrates taken in food are ordinary cane sugar, glucose, sugar of milk, and starches, such as wheat starch in bread, oat starch in oatmeal, rice starch in rice, and so forth. It must also not be lost sight of, that meat contains a carbohydrate (inosite). When a larger quantity of carbohydrate is consumed than is necessary for the needs of the body, it is stored up in the liver under the form of glycogen, and given out to the blood as required; hence a healthy person will never have more sugary substances in his circulation and secretions than normal. When this storehouse faculty of the liver becomes profoundly out of order, the disease known as diabetes is produced.

(431) *Fats.*

All ordinary fats are combinations of fatty acids with glycerin; for instance, palmitin is a union of three molecules of palmitic acid with one of glycerin, stearin is the union of three atoms of stearic acid with one of glycerin; olein, caproin, carpylin, are all of analogous composition. Glycerin having the formula $C_3H_5\,(HO)_3$, it is obvious that instead of the three hydroxyls being replaced by three of the same fatty acid, they may be replaced by two fatty

acids of one kind and one of another, or even three different fatty acids, as for example :—

$$C_3H_5 \begin{cases} (C_{18}H_{35}O_2)_2 \\ C_{16}H_{31}O_2 \end{cases} = \text{Distear palmitin.}$$

$$C_3H_5 \begin{cases} C_{18}H_{35}O_2 \\ C_{18}H_{33}O_2 \\ C_4H_7O_2 \end{cases} = \text{Stear-oleo-butyrin.}$$

Animal fats afford several instances of this complex composition ; butter, for example, used to be considered as mainly composed of olein, stearin, palmitin, butyrin, with smaller quantities of caproin, caprylin, and rutin. The author has however shown that it is improbable that tributyrin exists in butter save in small quantities, but that the 5 per cent. of soluble acids are in the main united with glycerin as complex ethers. Animal fats generally are neutral in composition, not a few vegetable fats have a small quantity of free fatty acid. The fats when heated to 220° C. in a silver lined iron closed tube, with a little water split up into fatty acids and glycerin ; they are also decomposed by treatment with superheated steam, but the ordinary method used by the analyst is to saponify with potash or soda, and thus unite the fatty acid with the alkali, subsequently decomposing the soap with a mineral acid.

Fat when it reaches the first part of the intestines is emulsified by the pancreatic and other secretions, and is believed to be in great part absorbed as fat, but some portion is undoubtedly saponified.

The fat of the body is not entirely formed from the fat consumed. Lawes and Gilbert gave a pig food which contained one hundred parts of fat, but the fat produced in the pig was four hundred and seventy-two parts, or almost five times as much as that given as fat. Bees fed on pure sugar and water will produce wax. The accepted view from the foregoing and other experiments is that fat is formed partly from fat, partly from carbo-hydrates, and partly from albuminous matters.

(432) *Mineral Matters.*

In the pipe bowl of the earth, a slow oxidation by means of the air goes on for ever; beast and bird, king and peasant, are burnt

up; nothing remains but an ash. The phosphates of lime, magnesia, the chlorides of potassium and sodium, a little iron, silica, fluorine, and a few other substances, may be mechanically dissipated but preserve their form, when brain and nerve, muscle and all else that has built up the fabric of life has been totally changed to gaseous or fluid elements.[1]

A certain proportion of mineral substances is necessary for the development of growth, and for the maintenance of vigour. During growth when bone is being formed, lime and magnesia is absorbed and retained, but in the adult it is capable of proof, that there is mineral equilibrium, the earthy phosphates taken in are excreted by the bowels and kidneys. Mineral matters abound in food, seeds such as wheat are characterized by a large content of phosphates, leaves such as cabbages, roots such as turnips or carrots, give an ash in which the phosphates are comparatively speaking much less than in seeds. Fruits give ashes rich in carbonates derived from organic acids. The only mineral matter there is any craving for, is salt. Common salt is in all the fluids of the body, and seems a necessary constituent.

The malady called "rickets" is mostly of tuberculous origin. It was at one time thought to be due to a deficiency of phosphates in food, an improbable origin, for it would be difficult with a mixed diet to starve the tissues of opportunity of obtaining their phosphates; the condition of the bones in rickets is rather due to a want of power in the body to assimilate the phosphates and mineral substances presented to them.

(433) *Digestibility of Foods.*

It was early discovered that a chemical analysis of food was no accurate measure of its utility as a food; weight for weight foods of approximately the same composition have different values when passed through an animal body. Digestion is always imperfect; if it were perfect, that which passes away should not be able to nourish other animals; but this is so far from being the case that, to take an example, horse's dung will abound in particles of the oat or whole grains, so little acted upon as to be a food for birds.

[1] "Diet in Relation to Health and Work," by A. Wynter Blyth. *Health Exhibition Hand-book.* London, 1884.

Hence if it could be found what amount of food completely absorbed would maintain a particular individual in health, yet that person would have to eat over and above the quantity, just as the stoker of a steam-engine has to supply the fire with an excess of coal over the theoretical quantity required to drive the engine. Again, if by careful concentration of very digestible nutriment into a small bulk it is attempted to feed a person for a long time, considerable discomfort is produced, because the intestines require a certain bulk before they are stimulated to peristaltic action, and the resulting constipation from such concentrated food is likely to produce general disorder.

The various degrees of digestibility of foods have been found out in the following ways :—

(1) By experiments in the laboratory; the chemist submitting different foods to the action of the juice of the pancreas; of the stomach, &c. at a regulated heat for a regulated time.

(2) By experiments on the human body, in those rare cases in which a fistula or opening leading into the stomach has been caused by disease; or in healthy people, watching the stages of gastric digestion by the removal of the products by the stomach pump.

(3) By experiments on animals in which an artificial opening into the stomach has been made.

(4) By analysis of "the income and output," *i.e.*, of the food going into the body, and of the food residues (excreta) which pass out of the body.

Of these methods the last is by many degrees the most certain, for no unnatural condition or element is introduced; besides which, a food residue, which has passed the length of the whole canal, may with more confidence have its value subtracted from the food, than a food residue which has been submitted to the action of a small portion of the canal. In this last method of experiment in some cases a simple food has been taken, as for example, whole meal bread, in others a complex diet. With regard to feeding men or animals on simple foods it must be borne in mind that the digestible value of the food thus obtained may not be the same as when mixed with other foods, that is to say, that if a certain proportion of A is digested when taken alone and a certain proportion of B is digested when taken alone, and then equal parts of

A and B are given it does not follow that the digestible value of A and B will be the mean of the values found when they were exhibited separately, for under these circumstances sometimes more, sometimes less of one or the other constituent is digested. There are also individual differences in power of digestion; thus the author found that in his experiments on whole meal bread, one individual digested 88 per cent., another quantities varying from 83 to 84 per cent. of the dry substance.

The following table gives mean values according to the results of various experimenters:—[1]

	Parts digested of 100 parts of the perfectly dried solid.	Amount of solid food passing away from the body by the alimentary canal.
Sugar	100·00	
Rice	96·0	4·00
Wheaten bread	95·00	5·00
Roast meat	94·80	5·20
Hard boiled eggs	94·75	5·25
Milk and cheese in the proportion of 2·4 : 1.	94·00	6·00
Corn flour	93·30	6·70
Milk and cheese in the proportion of 2 : 1	93·20	6·80
Milk (830 parts of fluid : 100 of solid	91·0	9·00
Potatoes	90·60	9·40
Rye bread	88·9	11·1
Milk and cheese equal parts of dry solids	88·7	11·3
Whole meal made into bread or cakes	84·5	15·5
Black bread	83·0	17·0
Carrots, Celery, Cabbage	76·0	24·0
Peas, Beans	52·4	47·6
Gelatin	50·0	50·0

The word digestion in the table is used in its physiological sense, that is, digestible foods of which small residues leave the body—indigestible foods of which large residues leave the body, it does not at all follow that the latter cause discomfort. The popular meaning of "indigestible" is at variance with the above, for it is used to denote those foods which by evolving gas cause distension, or by the formation of soluble products give rise to headache, nausea, or other signs of slight poisoning.

[1] In particular the experiments of Rubner, *Zeitschrift f. Biologie*, 1879, s. 118; of G. Meyer, *ibid.*, 1871, I.; of A. Strumpell, *Centr. f. medicin. Wissen.*, 1876; of H. Weiske, *Zeitsch f. Biol.*, 1870, s. 456; and of the author, in *Proceedings of the Royal Society*, vol. xlv.

(434) *The Standard Diet.*

A large amount of work has been done in comparing and chemically analysing foods of various nations and of persons of various ages and occupations; and the results have been reduced to food equivalents, so that it is now known what quantity of the four constituents of solid food is necessary to support ordinary labour.

The standard diet for adult men of the average weight of 150 lbs. in this climate is as follows:—

	Ozs.[1]		Grains.
Albuminoids	4·2	=	290 nitrogen.
Fat . . . . } Carbohydrates . . . . . }	18·7	=	4184·4 carbon.
Salts	1·05	=	459·3 mineral substances.

(435) *Construction of Dietaries.*

The Medical Officer of Health is rarely called upon to construct a dietary, but he may often have to criticise one and to reduce it to equivalents.

In the construction of a diet, it is not enough to ensure that the proper quantity of albuminoids,[2] fat, sugar, and mineral substances are supplied; but there must be variety, and there must be, especially in cases where salt meat is taken, fruits, or fresh vegetables introduced, in order that scurvy be prevented. From a food chemist's point of view the statute compelling British shipowners to supply sailors with a daily amount of limejuice, should be

[1] The nitrogen in grains may be calculated by multiplying the albuminoids (ozs.) by 69, the carbon by multiplying by 233. The carbon derived from the fat may be obtained by multiplying by 345·6, and from the carbohydrates other than sugar by multiplying by 194·2.

[2] Whether the albuminoids are derived from the vegetable or the animal kingdom entirely is a matter of indifference, and mainly regulated by custom. Vegetarians have taken much pains to show that meat is unnecessary and even hurtful, but the truth is that there are whole tribes who live on meat alone and enjoy high health, others living on fruits and vegetables alone who also enjoy high health. The question of vegetarianism is not to be settled by chemical research, it is rather a question of morality and æstheticism. On both these points the position of the vegetarian is an extremely strong one, and it is a pity that he should weaken it by arguments drawn from comparative anatomy and other sources which have only an indirect bearing upon the subject.

repealed, for it acts indirectly in permitting bad salt food to be given, and so long as the regulated amount of limejuice be served to the men the owners escape punishment; the common sense method is to allow shipowners perfect freedom to feed the men how they please; but should scurvy break out on a vessel and it be proved to be due to an ill-arranged dietary, then subject the parties responsible to a severe penalty. With the numberless contrivances to dry, tin, or bottle vegetables there is absolutely no need for lime juice.

In the construction of diets and also in their comparison use may be made of the following tables.

The way the tables are to be used is best shown by an example. A dinner consists of 2 ozs. of moderately fat beef, 4 ozs. of potatoes, 4 ozs. of cabbage, and 5 ozs. of bread, it is required to express this in food equivalents.

The percentage composition of fat beef will be found in Table XLVII. hence, as it is now required to know the "equivalents of 2 ozs."; each of the numbers in the table will have to be multiplied by $\frac{2}{100}$, that is ·02, the result will be, water 1·44 oz., albuminoids ·43, fat ·10; ash (mineral substances) ·03. Similarly the percentages of the components of the potato (Table LI.) have to be multiplied by $\frac{4}{100}$ or ·04, of the cabbage (Table LI.) by $\frac{4}{100}$ or ·04, and the percentages of bread by ·05.

The whole 15 ozs. are then expressed in ozs. and tenths as follows:—

TABLE XLVI.

	Water.	Nitrogenous substances.	Carbo-hydrates.	Fat.	Ash.
The 2 ozs. of beef equal . .	1·44	·43		0·10	·03
The 4 ozs. of potatoes . .	3·03	·07	·82	0·01	·04
The 4 ozs. of cabbage . . .	3·60	·07	·20	0·01	·05
The 5 ozs. of bread . . .	1·92	·34	·04	2·62	·06
	9·99	·91	1·06	2·74	·18

The total adds to 14·88 ozs. the woody fibre not being included.

TABLE XLVII.

PERCENTAGE COMPOSITION OF VARIOUS FORMS OF ANIMAL FLESH OR MEAT.

	Water.	Nitrogenous substances.	Fat.	Nitrogen free extractive matter.	Ash.
Bacon fat, salted and dried	13·9	9·0	74·1	...	3·0
Beef (fat) minimum	32·49	10·87	5·80	...	0·75
Beef (fat) maximum	73·50	19·94	56·11	...	1·53
Beef (fat) mean	54·76	16·93	27·23	...	1·08
Beef (moderately fat) minimum	68·50	16·99	1·00	...	0·75
Beef (moderately fat) maximum	78·00	25·03	9·86	...	2·02
Beef (moderately fat) mean	72·25	21·39	5·19	...	1·17
Beef (lean) minimum	75·21	20·18	0·61	...	1·14
Beef (lean) maximum	78·16	22·17	3·46	...	1·20
Beef (lean) mean	76·71	20·61	1·50	...	1·18
Fowl	70·82	22·65	3·11	2·33	1·09
Hare	74·16	23·34	1·13	0·19	1·18
Kidney (sheep's)	78·60	16·56	3·33	0·21	1·30
Mutton very fat	47·91	14·80	36·39	0·05	0·85
Mutton moderately fat	74·79	18·11	5·77	...	1·33
Pig's liver	72·37	18·65	5·66	1·81	1·51
Pork (fat) minimum	40·27	12·55	28·03	...	0·47
Pork (fat) maximum	54·63	16·58	46·71	...	1·07
Pork (fat) mean	47·40	14·54	37·34	...	0·72
Pork (lean) minimum	69·32	17·32	3·73	...	0·98
Pork (lean) maximum	76·14	24·47	11·77	...	1·64
Pork (lean) mean	72·18	19·91	6·81	...	1·10
Tripe	67·1	13·3	17·1		2·50
Veal (fat)	72·31	18·88	7·41	0·07	1·33
Veal (lean)	78·82	19·86	0·82	...	0·50
Eggs (hens)	73·67	12·55	0·35	...	1·12
Egg albumen	86·49	12·67	0·25	...	0·59
Egg, yelk of	50·79	17·24	31·75	0·13	1·09

TABLE XLVIII.

PERCENTAGE COMPOSITION OF FISH.

	Water.	Nitrogenous substances.	Fat.	Nitrogen free and extractive matter.	Ash.
Codfish	77·50	18·50	3·00	...	1·00
Eels	79·91	13·57	5·02	0·39	1·11
Gudgeon	76·89	17·37	2·68	...	3·44
Herrings, fresh	80·71	10·11	7·11	...	2·07
Herrings, salted	47·12	18·97	16·67	...	17·24
Herrings, smoked	69·13	21·12	8·51	...	1·24
Lamprey	51·21	20·18	25·59	1·61	1·41
Mackerel, fresh	68·27	23·42	6·76	...	1·55
Mackerel, salted	48·43	20·82	14·10	0·38	16·27
Oyster	89·69	4·95	0·37	2·62	2·37
Pike	77·37	19·86	0·79	1·60	0·38
Salmon	71·50	18·75	6·22	2·95	0 58
Sardine (preserved)	51·77	22·30	2·21	...	23·72
Skate	73·79	24·03	0·47	...	1·71
Sole	86·14	11·94	0·25	0·45	1·22
Sprat	59·89	22·73	15·94	0·98	0·46
Whiting	82·95	15·09	0·38	0·50	1·08

TABLE XLIX.

PERCENTAGE COMPOSITION OF MILK, CHEESE, AND OTHER DAIRY PRODUCTS.

	Water.	Casein and Albumin.	Fat.	Milk sugar.	Ash.
Milk	87·55	3·41	3·64	4·69	0·71
Skim milk	90·11	3·37	0·46	5·34	0·72
Cream	28·58	1·42	67·62	2·25	0·12
Devonshire cream	28·68	4·05	65·01	1·77	0·49
Buttermilk	90·62	3·78	1·25	3·38	0·65
Condensed milk (preserved with cane sugar)	24·42	10·33	9·02	milk sugar 12·64	1·93
	...	...	...	cane ,, 41·66	...
Condensed milk (without addition)	28·99	17·81	15·67	2·53	35·00
Butter	14·14	0·86	83·11	0·70	1·19
Butterine	12·01	0·74	82·03	...	5·22
CHEESE.					
1. Soft Cheese—					
Fromage de Brie	51 87	18·30	24·83	...	5·00
Camembert	51·30	19·00	21·50	3·50	4·70
Roquefort (fresh)	11·84	85·43	1·85	Lactic acid ·88	
2. Hard Cheese—					
American cheese	22·59	37·20	35·41	...	4·80
Cheddar cheese	27·83	44·47	24·04	...	3·66
Dunlop cheese	38·46	25·87	31·86	...	3·81
Gloucester (single)	21·41	49·12	25·38	...	4·09
Stilton (fresh)	32·18	24·31	37·36	2·22	3·93
Gruyere	34·68	31·41	28·93	1·13	3·85
Gorgonzola	43·56	24·17	27·95	...	4·32
Parmesan	27·56	44·08	15·95	6·69	5·72
Skim cheese	48·02	32·65	8·11	6·80	4·12

TABLE L.

PERCENTAGE COMPOSITION OF VARIOUS FLOURS AND LEGUMINOUS MEALS.

	Water.	Nitrogenous substances.	Fat.	Starch, &c.	Woody fibre.	Ash.
1. MEAL.						
Barley meal	15·06	11·75	1·71	70·90	0·11	0·47
Buckwheat meal	14·27	9·28	1·89	72·46	0·89	1·21
Maize	12·50	9·50	3 60	70·70	2·00	1·70
Oatmeal	10·46	15·50	6·11	63·67	2·24	2·02
Rye meal	14·24	10·97	1·95	69·74	1·62	1·48
Wheaten flour (fine)	14·86	8·91	1·11	74·18	0·33	0·61
,, ,, (seconds)	12·18	11·27	1·22	73·65	0·84	0·84
Whole meal	13·56	12·66	1·82	67·77	2·66	1·53
2. STARCH.						
Arrowroot	16·52	0·88		82·41	...	0·19
Maize starch	11·90	2·37		85·30	...	0·43
Sago	12·89	0·81		86·11	...	0·19
Tapioca	13·3	0·63		85·95	...	0·12
Wheat starch	11·30	1·12		87·05	...	0·53
Macaroni (stars)	14·01	8·69	0·32	76·49	...	0·49
,, (pipe)	15·86	8·19	0·29	75·06	...	0·60
3. LEGUMINOUS SEEDS.						
Beans (fresh and green)	86·10	4·67	0·30	6·60	1·69	0·64
,, (dried)	14·84	23·66	1·63	49·25	7·47	3·15
Peas (green)	80·49	5·75	0·50	10·86	1·60	0·80
,, (dried)	14·31	22·63	1·72	53·24	5·45	2·65
,, (shelled)	12·73	21·12	0·82	60·94	2·64	1·75
Pea meal (dried)	8·12	28·10	2·97	50·17	8·02	2·55
Kidney beans	88·36	2·77	0·14	1·20 Sugar 6·82	1·14	0·57
Lentils	12·51	24·81	1·85	54·78	3·58	2·47
Millet	11·26	11·29	3·56	67·33	4·25	2·31

Table LI.

Percentage Composition of Succulent Vegetables.

	Water.	Nitrogenous substance.	Fat.	Carbohydrates. Sugar.	Carbohydrates. Nitrogenous free extractive matter.	Woody fibre.	Ash.
Asparagus	93·32	1·98	0·28	0·40	2·34	1·14	0·54
Beet, common	87·88	1·07	0·11	6·55	2·43	1·02	0·94
Beet, sugar	83·91	2·08	0·11	9·31	2·41	1·14	1·04
Cabbages	89·97	1·89	0·20	2·29	2·58	1·84	1·23
Carrots	87·05	1·04	0·21	6·74	2·60	1·46	0·90
Celery, leaves	81·57	4·64	0·79	1·26	7·87	1·41	2·46
Celery, stalks	89·57	0·88	0·34	0·62	5·94	1·24	1·41
Cauliflower	90·39	2·53	0·38	1·27	3·74	0·87	0·82
Chicory, dried & roasted	10·69	6·29	1·52	15·54	55·00	6·11	4·85
Chicory, fresh	75·69	1·01	0·49	3·44	17·62	0·97	0·78
Cucumber	95·60	1·02	0·09	0·95	1·33	0·62	0·39
Garlic (leaves & stalks)	90·82	2·10	0·44	0·81	3·74	1·27	0·82
Horse radish	76·72	2·73	0·35	...	15·89	2·78	1·53
Lettuce	94·33	1·41	0·31	...	2·19	0·73	1·03
Onions (bulbs	64·66	6·76	0·06	...	26·31	0·77	1·44
Parsley	85·05	3·66	0·22	0·75	6·69	1·45	1·68
Potatoes	75·77	1·79	0·16	...	20·56	0·75	0·97
Radishes	93·34	1·23	0·15	0·88	2·91	0·75	0·74
Savoys	87·09	3·31	0·71	1·29	4·73	1·23	1·64
Spinach	90·26	3·15	0·54	0 08	3·26	0·77	1·94
Turnips	85·01	2·95	0·22	0·40	8·45	1·76	1·21
Water-melon	95·21	1·06	0·60	0·27	1·16	1·07	0·63

TABLE LII.

PERCENTAGE COMPOSITION OF FRUITS.

	Water.	Nitrogenous substances.	Free[1] Acid.	Sugar.	Nitrogen free substances, extractives, &c.	Cellulose and seeds.	Ash.
Almonds . . .	5·39	24·18	...	fat 53·68	7·23	6·56	2·96
Apple	83·58	0·39	0·84	7·73	5·17	1·98	0·31
Apricot	81·22	0·49	1·16	4·69	6·35	5·27	0·82
Bilberry . . .	78·36	0·78	1·66	5·02	0·87	12·29	1·02
Blackberry . .	86·41	0·51	1·19	4·44	1·76	5·21	0·48
Chestnut . . .	51·48	5·48	...	fat 1·37	38·34	1·61	1·72
Cherry	80·26	0·62	0·91	10·24	1·17	6·07	0·73
Cocoanut (white solid part). .	5·32	...	...	fat 66·16	...	?	1·55
Cocoanut milk .	91·50	0·46	...	fat ·07	6·78	...	1·19
Currant	84·77	0·51	2·15	6·38	0·90	4·57	0·72
Damson	81·18	0·78	0·85	6·15	4·92	5·41	0·71
Fig (as sold) . .	31·20	4·01	1·21 also fatty matter 1·44	49·79	4·51	4·98	2·86
Filberts	3·77	15·62	...	fat 66·07	9·03	3·28	1·83
Gooseberries . .	85·74	0·47	1·42	7·03	1·40	3·52	0·42
Grapes	78·17	0·59	0·79	24·36	1·96	3·60	0·53
Mulberries . .	84·71	0·36	1·86	9·19	2·31	0·91	0·66
Oranges . . .	89·01	0·73	2·44	4·59	0·95	1·79	0·49
Peaches . . .	80·03	0·65	0·92	4·48	7·17	6·06	0·69
Pears	83·03	0·36	0·20	8·26	3·54	4·30	0·31
Plums	84·86	0·40	1·50	3·56	4·68	4·34	0·66
Raisins	32·02	2·42	...	54·56 also fatty matter 0·59	7·48	1·72	1·21
Raspberries . .	86·21	0·53	1·38	3·95	1·54	5·90	0·49
Strawberries .	87·66	1·07	0·93	6·28	0·48	2·77	0·81
Walnuts	4·68	16·37	...	fat 62·86	7·89	6·17	2·03

[1] The free acid is different in different fruits. The chief free acid of the apple, pear, plum, apricot, peach, and cherry is malic acid; that of the grape, tartaric acid; in oranges and lemons, citric acid; and in strawberries and raspberries the acidity is due to a mixture of citric and malic acids.

SECTION XI.

THE DUTIES OF SANITARY OFFICERS.

CHAPTER XXXV.

THE DUTIES OF SANITARY OFFICERS.

Duties and Qualifications of Medical Officers of Health.

(436) *Qualifications of Medical Officers of Health.*

The qualifications of a Medical Officer of Health are expressly laid down by the Local Government Act, 1889, sect. 18. "Except where the Local Government Board, for reasons brought to their notice, may see fit in particular cases specially to allow, no person shall hereafter be appointed the Medical Officer of Health of any county or county district, or combination of county districts, or the deputy of any such officer, unless he be legally qualified for the practice of medicine, surgery and midwifery.

"No person shall after the 1st of January, 1892, be appointed the Medical Officer of Health of any county or of any such district or combination of districts as contained according to the last published census for the time being a population of 50,000 or more inhabitants, unless he is qualified as above mentioned, and also is either registered in the medical register as the holder of a diploma in sanitary science, public health or State medicine under section 21 of the Medical Act, 1886, or has been during three consecutive years preceding the year 1892, a Medical Officer of a district or combination of districts, with a population, according to the last published census of not less than 20,000, or has before the passing of this Act been for not less than three years a Medical Officer or Inspector of the Local Government Board."

The qualifications then with regard to future appointments are, adequate experience in a sufficiently populous place, or passing a particular examination.

(437) *Duties of Medical Officers of Health.*

There are at the present time several classes of Medical Officers of Health.

I. Medical Officers of Health for a county, as for example the county of London.

II. Medical Officers of Health for exclusively urban districts, as for example Metropolitan Health Officers, or those for Liverpool, Manchester, Bradford.

III. Medical Officers of Health for a port sanitary district.

IV. Medical Officers of Health for combined rural and urban districts.

V. Poor-law Medical Officers, acting as Medical Officers of Health and others. This last class of appointments is profoundly unsatisfactory ; individual officers here and there do good work, and this is cited as a defence of the system ; but as a rule the appointments of this nature are only colourable, and the duties are insufficiently performed by medical men whose occupations do not admit of their paying the requisite attention to the subject.

I. *Duties of County Medical Officers of Health.*

This class of officers, created by the Local Government Act of 1889, has so recently been called into existence that there is but little experience as yet as to the nature of the duties. It is, however, obvious, that presuming the County Officer has official connexion with Officers of Health of the districts, he will receive regularly all the reports annual, monthly, or special that they have submitted to their respective authorities. He will tabulate and study the statistics relative to sickness and mortality. He will personally with the aid of the local Medical Officer of Health investigate any unusual incidence of disease. He will, where necessary, urge upon the local authority to undertake schemes of sewerage or water supply. His advice will be specially valuable in drawing out local regulations as to offensive trades, the framing of bye-laws and the like. The legislation which is now confidently expected in the formation of district councils will, without doubt, define the relation that the County Council will have to the district boards, and make this outline of the duties possible to be put into practical effect.

II. *Duties of Urban Medical Officers of Health.*

In urban districts there is a good deal of variety in the duties. Some urban districts, like those of the metropolis, are governed by special, local or general Acts. For example, the City of London has a code of laws differing in detail from the rest of the country; the other metropolitan districts are governed by the Metropolis Local Management Acts, by the Sanitary Act of 1866, by the Nuisance Removal Acts and several others. (The Public Health Acts as a whole are not in force in the metropolis.) Hence the duties laid down by the Local Government Board (see page 601), are not in force in the metropolis,[1] but they are chiefly regulated by custom and by resolutions of the Vestry or District Board. Similarly local Acts obtained from time to time modify the details of the work in some urban districts. Nevertheless as a whole they are similar in all, and in the following sketch, the details of official duty are those which seem to the writer, from his personal experience and from a study of what is actually done in the model urban districts, as likely to ensure efficiency of local health administration.

(*a*) *Attendance at the Health Office.*—It is essential that the Health Officer attend with the greatest regularity at stated and published times at an office provided by the Local Authority in order that he can interview the inspector or inspectors, give them directions, and be accessible to any person who desires personally to lay a complaint or to consult the Health Officer.

(*b*) *Supervising the Work of the Inspectors.*—The Inspectors should be compelled to submit each morning a diary of the work of the preceding day; the diary being written with sufficient detail to show exactly how they have been employed, what visits they have made, and so forth. Their outside work should be checked by occasional visits of the Health Officer to premises previously visited by the Inspectors, and by comparing the state as reported by the Inspector with the state found. The Medical Officer of Health will particularly note any grave defects which may have been passed over by the Inspector, thereby proving incompetence or negligence.

(*c*) *Inspection of Premises.*—The Health Officer should personally inspect premises in certain cases, viz., when the Inspector's report is disputed; when legal action for the enforcement of a sanitary order

[1] Save in those instances in which half the salary is paid by the L. G. B.

is considered necessary; in the special cases in which illness is said or supposed to be due to the sanitary condition of premises; in all cases of complaint of nuisance caused by noxious trades. He should also make from time to time house to house inspections of houses let in lodgings (tenement houses), and registered lodging-houses.

(*d*) *Inspection of Bakehouses, Slaughterhouses, and Cowhouses.*—In these cases also the Medical Officer of Health should make personal inspections ; he is indeed required by law to inspect personally bakehouses, for it is he alone who is recognized by the Factory Act. It is also advisable for the Medical Officer of Health to inspect at least once a year personally cowhouses and slaughter-houses.

(*e*) *Supervision of the Water Supply.*—It is to be presumed that all urban districts have a public water supply. It is evidently the duty of the Health Officer to watch the supply narrowly. Taking the simplest case in which a water company and one only, supplies a district. To guard against chance pollution from defective ferrules or supply pipes or faulty conditions of the main itself, it will be necessary to take on the same day a number of samples, and by chemical analysis to ascertain whether they are all of practically identical quality. No elaborate analysis is necessary for this, 50 c c. of each may be placed in a glass cylinder and equal quantities of Nessler solution run in. The colouration should, of course, be all equal. A determination of chlorine should also be made of each (see page 169), this ought also to be equal. Should the simple examination detailed show equality in chlorine and in colouration on the addition of Nessler, an analysis of one sample will then be an analysis of the whole. Should there be any difference found, then that particular sample should be most carefully analyzed and the reason of the difference ascertained by examining the fittings in the house, the supply pipe under the street and so forth.

(*f*) *Work under the Notification Act.*—Every urban district will, without doubt, have to follow the majority of both urban and rural districts, and adopt the Infectious Disease Notification Act. It will be the duty of the Medical Officer of Health to cause an inquiry to be made as to the state of any premises in which infectious disease has been notified. In the writer's opinion a certificate under the Act justifies a demand for entry by the officer, for he has reasonable cause to suspect a nuisance. He will also insist upon disinfection on

recovery, death, or removal of the patient. Any inquiry as to infectious disease will be incomplete if it does not embrace the antecedent history of the patient for some days before the period of incubation of the particular malady. Take for instance enteric fever, then the history of the patient must go back at least three weeks before the date of first symptoms. If the sufferer is a child and has attended school it is the duty of the Medical Officer of Health to see that the school authorities be informed of the illness, and if the malady is infectious, *e.g.*, scarlet fever, other members of the family should not be allowed to go to school, so long as risk of infection remains. It will be the policy and duty of the Medical Officer of Health to remove compulsorily, where legally enabled to do so, or by persuasion, all infected persons to a hospital if such a building has been provided by the local authority; for it is obvious that early removal from population centres is the sheet anchor of disease prevention.

(*g*) *Records of Sanitary Condition—Routine Office Work.*—The Medical Officer of Health should aim at the high ideal of endeavouring to collect in his office details as to the drainage, water supply, construction, tenancy and disease history of every single house in his district. The information should be contained in indexed books, so that at any time, he can in a few minutes give the whole sanitary history of the house. If this were done, all persons for the first time entering or contemplating to enter into residence, whether as lodgers or in permanency, would apply at the health office and get that information which can now only be laboriously obtained by applying to several distinct persons supplemented often by a somewhat expensive investigation. No small amount of office work is taken up with correspondence. It is scarcely necessary to say that all letters going out of the office should be copied, and a copy kept in an indexed book, and all letters coming into the office should be stamped with the date of receipt and filed. The author uses a Shannon file, but any arrangement which admits of easy and quick reference to a particular letter will answer the purpose.

In indexing and keeping correspondence or other documents it is found in practice best to keep each year separate.

(*h*) *Enforcement of Sanitary Orders.*—The method of enforcement of sanitary orders varies a little in different districts. The

author goes over all the orders of the vestry week by week, and marks those which are completed with the date of completion ; as to those that are not completed, he has a special report from the inspector. If not complied with, and it is in his opinion necessary to take legal proceedings to enforce the same, he passes the order on to the vestry clerk, who on consultation with the solicitor directs the inspector of nuisances to take out a summons. In most districts, all cases for summons go before a committee, or the sanitary authority, a procedure which entails delay and inequality of action. Inequality of action is inseparable from any process which is dependent upon a show of hands. The proper way is to treat all sanitary orders of a routine character as orders which are to be enforced by law, and once therefore the order has been given by the sanitary authority for a particular owner to do a certain work it should by implication be the duty of the clerk to the authority to put the usual machinery in motion without a fresh report to the local authority. On the other hand, matters out of the usual routine, and more particularly prosecutions involving large interests and possibly entailing considerable expense, should be specially brought before the authority and the necessary powers to proceed obtained. Once an order is reported as not obeyed, the Health Officer's responsibility for the time ceases until a magistrate's order is obtained; it is then his duty to see whether the magistrate's order is obeyed or not, and to report the same to the sanitary authority.

(*i*) *Reports of an Urban Medical Officer of Health.*—The reports may be divided into two classes; those which are mere summaries of past events, and those which are reports upon present condition, and usually require some action to be taken by the sanitary authority. Among the first class are the ordinary periodical reports—weekly, monthly, quarterly, annual.

It may be taken as a principle that every ratepayer in an urban district has a right to be informed periodically of the health of the district. Hence in towns of sufficient size, the reports of the Health Officer which appear in a periodical form should be printed and circulated. The circulation should not only be amongst the members of the sanitary authority, but should be sent to all medical practitioners, to all local libraries and institutions, and to any resident who desires a copy.

Such reports usually contain weekly meteorological returns, births and deaths, sickness returns under the Notification Act, brief accounts of any epidemic which has prevailed, of the results of prosecutions and other kindred matters; the whole written without padding with extraneous material. It is to the author's mind an abuse of such reports to make them the vehicle of hobbies, of controversial questions, or to ventilate therein the great social questions of the day. The aim of the periodical reports should be mainly historical, to put in a more or less permanent form the local sanitary history of the district. The Health Officer cannot take a better example than the weekly health return for the city of Manchester, issued by Dr. Tatham; for instance, the return for the week ending January 25th, 1890, is thus arranged:—

(1) Meteorology, sickness, and condition of the public health.

(2) Notification and local distribution of cases of infectious sickness.

(3) Hospital isolation of patients suffering from infectious diseases.

(4) Comparative statistics of births and deaths in recent weekly periods.

(5) Local distribution of deaths in registration sub-districts. Pauperism[1]—weekly number of persons relieved by the Guardians.

(6) Register of sanitary work done during the week.

This last is as important as any (although probably the least read); as the form of Dr. Tatham's register seems to be generally useful the author has adopted it, and it may be well to reproduce it:—

Example of Dr. Tatham's Weekly Register.

REGISTER OF SANITARY WORK.

Week ending 25*th January*, 1890:—

NUISANCE DEPARTMENT.

Number of Complaints Received	From Public	33
	Special, from Medical Officer of Health . .	6

[1] Pauperism is intimately connected with sanitary condition, but some may take exception to this being included. It is of course not absolutely essential.

NUISANCE DEPARTMENT (*continued*).

Inspections	Of Dwelling-houses	838
	,, Cellars	5
	,, Schools	1
	,, Lodging-houses	114
	,, Dairies and Milkshops	175
	,, Bakehouses	37
	,, Canal Boats	0
	,, Tips for Refuse	0
	,, Miscellaneous Inspections	394
Smoke Abatement	Observations Made	17
	Proceedings taken before Magistrates	3
Food Adulteration	Samples collected for Analysis	40
	Proceedings taken before Magistrates	0
Ashpits reported to Health Department for Emptying		98
Notices issued for Abatement of Nuisances		315
Letters Written for Abatement of Nuisances		53
Reports made to Medical Officer of Health		9

HEALTH DEPARTMENT.

Infectious Patients removed to Hospital	29
Infected Articles Removed and Stoved	289
Rooms Fumigated after Infectious Disease	98
Rooms Stripped and Dressed with Caustic Soda after Infectious Disease	43
Visits by Disinfectors on account of Infectious Disease	180
Pails Emptied during the week (number)	83,000
Ashpits Emptied during the week (number)	197
Tons of Refuse Removed from amidst the homes of the people	4,713
Square Yards of Street Surface Swept and Cleansed	8,142,828
Number of Courts and Passages Swilled with Water	355

MARKETS DEPARTMENT.

Unwholesome Food—Number of Seizures made	5

PUBLIC HEALTH OFFICE.

Notifications of Infectious Attacks received and Registered	54
Statistical Returns to Government and other Departments, &c.	228
Cautionary Notices to Schools *re* Infectious Sickness	22
Cautionary Notices to Libraries *re* Infectious Sickness	0

The same principles that have been laid down with respect to monthly or weekly or quarterly reports are applicable to annual reports. They should be simple chronicles showing the sanitary work, the sickness, and the movement of the population so that the ordinary reader will be able to grasp fairly the condition of the district. The bulky, over tabulated, and expensive annual reports issued by several urban Health Officers, should not be taken as models; many of them are stuffed out with discussions of matters not directly affecting the district; above all things let the report be local; the information accurate, and as much as possible stick to facts. Reports ought to be all on one uniform plan, and it

would even be convenient if they were of one uniform size. Spot maps and the graphic method of representing statistics are to be commended. In the best spot maps, the ground-work of the map is shaded according to the density of the population; from those not thus shaded, a person who does not know the density of the population might draw the erroneous deduction that a portion thickly speckled with scarlet fever deaths had a serious meaning, although the greater incidence on that part was due merely to superior density of population. A sickness spot map is far superior to a mortality spot map, for it not unfrequently happens that in, for instance, typhoid fever, a large number of cases may occur which result in but few deaths. The very general adoption of the Infectious Disease Notification Act will now enable Medical Officers of Health to make spot maps of their districts for those particular maladies which cannot but be valuable. In Manchester it may be mentioned the Health Officer sends a spot map (disease chart) to each of the free public libraries and public reading rooms every week.

In the future, photography will also be largely used both as a convenient means of record and also as useful evidence in legal proceedings—the more especially since successive improvements in the instruments have rendered the operation itself simple and learned with facility. The following figure (Fig. 53), copied from one of Dr. W. J. Simpson's Reports of the Health of Calcutta, at once shows the great utility of a photograph. The picture clearly represents excessive pollution of earth and water and faulty excrement disposal.

The other class of reports are mostly made with a special object in view, that is to represent to the authority the desirability of doing something, or else they are special reports upon the action taken by himself or officers. If the Medical Officer of Health makes any recommendation, its best position is at the end of the report, and such recommendation should be in the clearest and most precise language. Once having recommended a course of action to a sanitary authority, and the course of action recommended having been ignored, the responsibility lies altogether on the authority, and is taken away from the Health Officer. It is therefore unwise on his part to show any irritation on the subject, or to caustically allude to it in subsequent reports. If the matter

reported upon is of real importance and he considers it essential

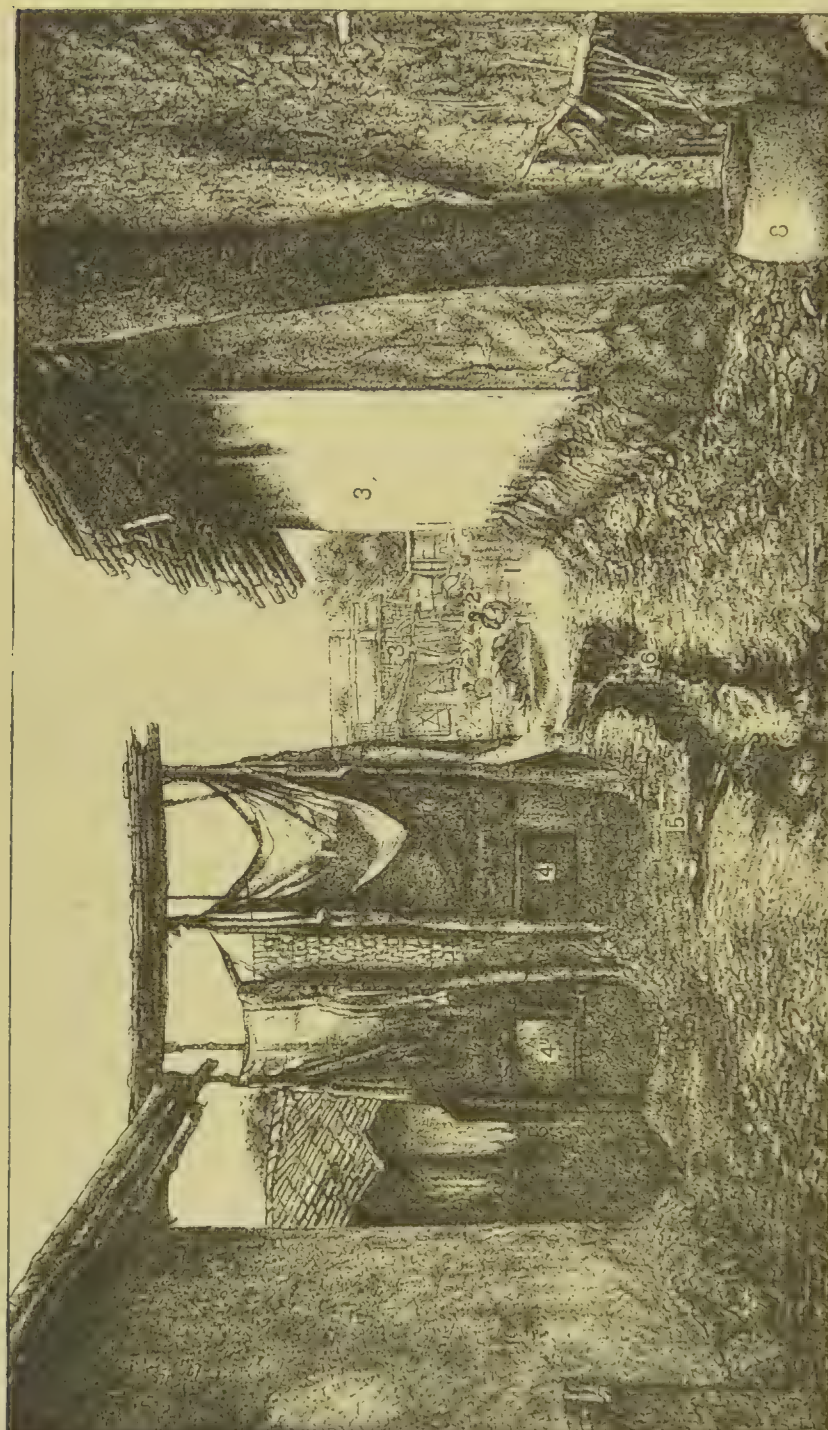

FIG. 53.—TANK IN A CALCUTTA BUSTEE WITH HUTS AND PRIVIES ON ITS EDGE.

1. Tank.
2. Bather.
3. Huts on border of tank.
4. Privies on bank of tank.
5. Drains from privies.
6. Drain running into tank.
7. External opening of a privy situated inside hut.
8. Gumlah or vessel to receive privy washings.

for the public health of his district, a good opportunity may be waited for, and the identical thing recommended in a different

way. Experience shows that a really necessary thing is ultimately carried, although the opposition at first be violent and demonstrative.

(438) *Duties of a Port Medical Officer of Health.*

Duties appertaining to an officer having charge of a port of some size will alone be considered, those pertaining to the smaller ports being only different in the amount of inspecting necessary to be performed. It must be borne in mind that by sect. 110 of the Public Health Act, all ships save those belonging to Her Majesty's Government, or to foreign governments are as regards nuisances to be treated as houses. The old quarantine Act of George IV. is still in force, but the chief regulations respecting the duties of sanitary officers are contained in the general orders of the Local Government Board of 1883.

The duties of a Port Health Officer may be divided into ordinary routine duties, and to special duties with regard to possible cholera invasion.

The ordinary routine duties in respect to the supervision of the inspectors, attendance at an office, &c., are not different to those of other Health Officers.

Naturally the most important work is in reference to the inspection of incoming vessels in which there is reason to suspect that sickness is on board. This knowledge is obtained in various ways; in a properly arranged Port Health Office, the daily and medical press is methodically perused for the purpose of learning of the existence of disease in foreign or home ports, and by the aid of the information thus acquired and from the *Shipping Gazette*, the vessels expected, and the approximate times of their arrival are obtained. Such ships are visited without delay, either by the Medical Officer of Health personally, or by his inspectors. Under the Quarantine Act also all diseases whatsoever on board vessels entering a port and not arriving coastwise are to be reported to the Customs, who detain the ship until she is released by the Health Officer of the port. The Customs therefore report these cases to the Health Office, and it is one of the most essential duties of a Port Medical Officer of Health to board such vessels, and to see the cases of illness, and to ascertain whether the illness is one of an

infectious nature or not. If the disease is infectious, then by section 125 of the Public Health Act, the patient may be removed from the vessel to a hospital. In large ports also the sanitary authority have made, under section 125 of the same Act, notification and disinfection compulsory on the masters. There is then this important and essential difference in the duties of land and port Medical Officers of Health. In the latter, it is no part of routine duty to visit cases of sickness for the purpose of diagnosing disease, but with the Port Medical Officer of Health, he may be daily obliged to investigate for himself the nature of the sickness, and cause the patient to be removed or not according to circumstances, and the vessel to be detained until properly disinfected.

The special duties in connection with apprehended cholera invasion are of two kinds, viz. (1) the obtaining full and early information respecting the disease, and (2) those involved in preventing the spread of infection.

The channels through which information is obtained are thus summarized by Dr. Armstrong :—[1]

1. Vigilant observation of records of cholera in foreign countries.
2. Arrangements with the Customs, for the earliest possible information of arrivals of infected or suspected vessels, or vessels from infected countries.
3. The publication of printed information in the port on the subject of "Cholera and its prevention."
4. Careful inquiry into the water supply of ships.
5. Inquiry into cases of ailment of a suspicious character on shipboard (diarrhœa, &c.).
6. The engagement of a sufficient staff.
7. The keeping of a "Homeward-bound Register."
8. The provision of special accommodation for cases of cholera.

(See also *ante* in the chapter on cholera.)

(439) *The Report of a Port Medical Officer of Health.*

In the 16th Annual Report of the Local Government Board (Supplement) is given Mr. Armstrong's annual report to the River Tyne Port Sanitary Authority for the year ending December 31st, 1886, as an example. It would therefore be well, as this report has

[1] *Public Health*, vol. i. p. 40.

received official sanction, to follow its arrangement as far as practicable. The following is a general outline of the report:—

1. *Infectious Disease in the Port.*—Under this heading is given a short succinct history of the cases of infectious disease admitted into the isolation hospitals, the diseases reported on various vessels from foreign ports and similar matters.

2. *Cholera Precautions.*—In this section details of the special precautions against the importation of cholera are given, and a table shows the number of vessels which arrived from infected ports during the year.

3. *Hospital Accommodation.*—Under this heading the nature of the existing hospital accommodation is given.

4. *General Sanitary Work.*—This is the most important part of the report. It gives the total number of vessels arriving in the port, the total number of vessels inspected, their nationality, and a summary of their sanitary condition.

The number of notices served to abate nuisances or structural or other defects are given as follows:—

	Cases.	Defect remedied on notice.	Pending.
Defective ventilation	8	7	1
Iron deck to line with wood	21	16	5
Defective bulkhead	5	3	2
Defective drainage	12	10	2
Defective lighting	5	4	1
Defective water-closet	10	10	...
	61	50	11

Notices were also served or orders to abate nuisances to remedy sanitary defects, either in the crew spaces, closets, peaks, holds, or bilges, as follows:—

British steamers	338
British sailing vessels	116
Foreign steamers	98
Foreign sailing ships	99
	651

(440) *The Duties of a Medical Officer of Health in a Combined District.*

These are somewhat different in detail. If the district is of any great extent it is practically impossible for the Health Officer to attend daily at any office, and personal interviews must take place

by appointment. In the same way supervision of the inspector's work can only be intermittent. Nevertheless the examination of their diaries should never be omitted, and their capability tested by noting any mistakes of omission or commission with respect to premises which have been inspected by them. It is specially important in a combined district for the Health Officer at least once a year to visit every village and town to ascertain the purity of the water supply, the proper disposal of the sewage, and the general health. In this annual survey he should place himself in communication with the clergymen of the different parishes, the relieving officers, with the schoolmasters, with the veterinary surgeons, with the medical men, and any others who are likely to afford him information.

No small amount of labour must be devoted in combined districts a great portion of which is of a rural character, to inspection of the dairy farms, and to see that the regulations given at page 275 are properly carried out. It is most decidedly the duty of the Health Officer to make a personal and detailed inspection at least once a year of every milk-producing farm.

(441) *The Reports of a Medical Officer of Health to a Combined District.*

It has hitherto been of necessity that separate annual reports to each of the authorities governing a combined district have been made ; in some districts there exists the requisite machinery enabling the medical officer to have these reports printed in one volume, in others this has not been done. It is obvious that the preferable plan is to give a summary of the whole combined district, and to follow this summary by the details belonging to each separate area, and to conclude with a subject index. It would also be useful if every Health Officer published each census year an index of the preceding ten years' reports; in this way reference could be made rapidly to the past history of the district.

(442) *Duties of Medical Officers of Health as laid down by the Local Government Board.*

The duties of a Medical Officer of Health have been laid down by the Local Government Board as follows :—

Duties.

The following shall be the duties of the Medical Officer of Health in respect of the district for which he is appointed ; or, if he shall be appointed for more than one district, then in respect of each of such districts :—

1. He shall inform himself, as far as practicable, respecting all influences affecting or threatening to affect injuriously the public health within the district.

2. He shall inquire into and ascertain by such means as are at his disposal the causes or origin and distribution of diseases within the district, and ascertain to what extent the same have depended on conditions capable of removal or mitigation.

3. He shall by inspection of the district, both systematically at certain periods and at intervals as occasion may require, keep himself informed of the conditions injurious to health existing therein.

4. He shall be prepared to advise the sanitary authority of all matters affecting the health of the district, and on all sanitary points involved in the action of the sanitary authority or authorities ; and in cases requiring it he shall certify, for the guidance of the sanitary authorities or of the justices, as to any matter in respect of which the certificate of a Medical Officer of Health or a medical practitioner is required as the basis or in aid of sanitary action.

5. He shall advise the sanitary authority on any question relating to health involved in the framing and subsequent working of such bye-laws and regulations as they may have power to make.

6. On receiving information of the outbreak of any contagious, infectious, or epidemic disease of a dangerous character within the district, he shall visit the spot without delay, and inquire into the causes and circumstances of the outbreak, and advise the person competent to act as to the measures which may appear to him to be required to prevent the extension of the disease, and, so far as he may be lawfully authorized, assist in the execution of the same.

7. On receiving information from the inspector of nuisances that his intervention is required in consequence of the existence of any nuisance injurious to health, or of any overcrowding in a house, he shall as early as practicable take such steps authorized by the statutes in that behalf as the circumstances of the case may justify and require.

8. In any case in which it may appear to him to be necessary or advisable, or in which he shall be so directed by the sanitary authority, he shall himself inspect and examine any animal, carcase, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, or flour, exposed for sale and intended for the food of man, which is deemed to be diseased, unsound, or unwholesome, or unfit for the food of man ; and if he finds that such animal or article is diseased or unsound or unwholesome, or unfit for the food of man, he shall give such directions as may be necessary for causing the same to be seized, taken, and carried away, in order to be dealt with by a justice according to the provisions of the statutes applicable to the case.

9. He shall perform all the duties imposed upon him by the bye-laws and regulations of the sanitary authority, duly confirmed, in respect of any matter affecting the public health, and touching which they are authorized to frame bye-laws and regulations.

10. He shall inquire into any offensive process of trade carried on within the district, and report on the appropriate means for the prevention of any nuisance or injury to health therefrom.

11. He shall attend at the office of the sanitary authority, or some other appointed place, at such stated times as they may direct.

12. He shall from time to time report in writing to the sanitary authority his proceedings, and the measures which may require to be adopted for the improvement or protection of the public health in the district. He shall in like manner report with respect to the sickness and mortality within the district as far as he has been enabled to ascertain the same.

13. He shall keep a book or books, to be provided by the sanitary authority, in which he shall make an entry of his visits and notes of his observations and instructions thereon, and also the date and nature of applications made to him, the date

and result of the action taken thereon, and of any action taken on previous reports, and shall produce such book or books whenever required to the sanitary authority.

14. He shall also prepare an annual report, to be made at the end of December in each year, comprising tabular statements of the sickness and mortality within the district, classified according to diseases, ages, and locality, and a summary of the action taken during the year for preventing the spread of disease. The report shall also contain an account of the proceedings in which he has taken part or advised under the Sanitary Acts, so far as such proceedings relate to conditions dangerous or injurious to health; and also an account of the supervision exercised by him or on his advice during the year in regard to offensive trades, bakehouses, and workshops.

15. He shall give immediate information to the Local Government Board of any outbreak of dangerous epidemic disease within the district, and shall transmit to the Board, on forms to be provided by them, a quarterly return of the sickness and deaths within the district, and also a copy of each annual and of any special report.

16. In matters not specifically provided for in this order, he shall observe and execute the instructions of the Local Government Board on the duties of Medical Officers of Health, and all the lawful orders and directions of the sanitary authority applicable to his office.

17. Whenever the Disease Prevention Act of 1855 is in force within the district, he shall observe the directions and regulations issued under that Act by the Local Government Board, so far as the same relate to or concern his office.

(443) *Duties and Qualifications of Inspectors of Nuisances.*

Qualifications.—An inspector of nuisances should of course be in good health and suffer from no physical infirmity interfering with his duties. On his first appointment his age should not be below twenty-one nor over forty; persons over forty, who for the first time apply for such a slenderly paid post as that of an inspector of nuisances, are as a rule men who have failed in other walks of life. On the other hand, these remarks do not apply to men seeking second or third appointments with good records; age in such cases must be considered on its merits—the writer has known very efficient inspectors, with great endurance and activity, over sixty years of age. The best foundation for a young inspector of nuisances is the requisite knowledge of the sanitary law, the principles of drainage, of water supply, and the methods of inspection generally, enabling him to have passed such an examination as that which is held several times a year by the Sanitary Institute; this examination once passed, and its teaching supplemented by the practical experience of a year's training as assistant inspector in a large urban or combined district.

The duties ordinarily devolving upon an inspector are set forth in sufficient detail in the Local Government Board's order printed at the end of this chapter. They naturally vary according as to whether the district is exclusively urban or urban and rural, or

whether the duties are those of a port sanitary inspector. In a great many districts it devolves upon the inspector to take, on behalf of the authority, legal proceedings. This he does by virtue of sec. 259 of the Public Health Act, which enables the local authority to appear before any court "by their clerk, or by any officer or member authorized generally or in respect of any special proceeding by resolution of such authority, and such person being so authorized is at liberty to institute and carry on any proceeding which the local authority is authorized to institute and carry on under the Public Health Act." Likewise in the metropolis it is the custom in more than one district for the inspectors of nuisances to take out summonses in their own name on behalf of the authority, and to conduct cases of routine without the aid of a solicitor.

It is questionable whether this is a wise course. It would seem more reasonable in all cases to employ a solicitor, in the way that the best local authorities do, or, should the clerk to the authority be legally qualified, to take proceedings by the clerk.

Dealing with things as they are, it is essential that the inspector should acquire a knowledge of the ordinary procedure of the police-court, and be able to fill up the summons, draw out a magistrate's order, and so on. All these matters are really simple.

The inspector of nuisances should be under the orders of the Medical Officer of Health. In many rural districts the inspectors enjoy too great a degree of independence, and are not so amenable to discipline as in urban districts; this is in a great measure due to the unsatisfactory appointment in the smaller districts of the poor-law officers as Medical Officers of Health.

As a rule the inspectors should have no other appointment and devote their whole time to their duties. The Local Government Board expressly state that it is undesirable that the office of relieving officer, or of superintendent of police, should be united with that of inspector of nuisances. On the other hand, in small districts, the office of surveyor, vaccination officer, inspector of weights and measures and inspector of markets, and the like public officers are often combined, and the combination is found to be conducive to economy and efficiency, provided the officer appointed is a man of suitable character and energy.

(444) *Duties of Port Sanitary Inspector.*

The only duties which may require special description will be those of a port sanitary inspector. In this case it is essential that the officer should know something of the management and construction of ships; a half-pay naval officer, who has passed the examination of the Sanitary Institute, should make an excellent inspector for a port. The Tyne port has three inspectors—one, the chief, was chief mate of a merchantman, the one assistant was a ship's carpenter, the other a sea-going engineer. The duties of these three officers are thus described by Mr. Armstrong[1] :—

The chief inspector attends at the station at 8.30 A.M. He examines the list of arrivals during the previous night and up to 8 in the morning, which is brought from the water-guard office by the assistant inspector on night duty. He instructs the assistant coming on duty at 9 o'clock; attends to correspondence; prepares list of arrivals to board and calls to make during the day; revises *Shipping Gazette* for reports of homeward-bound vessels; attends to any office work on hand. Then proceeds on steam-launch to board vessels, selecting first the most important, *e.g.* those from abroad or specially noted. If working the lower reaches of the river he returns to station about 1 P.M., and meets the assistant inspector of the day, who reports, and receives further instruction. The chief inspector, or the assistant on duty, calls at the water-guard office at 1.30 P.M. for list of arrivals. The afternoon is spent in visiting vessels on the river or in the docks, after which he returns to the station, and generally sends the launch to moor at 5 P.M. in winter or 6 P.M. in summer; again meets the assistant on duty and receives his report; completes any office work remaining. Revisits office at 8 P.M. to receive list of arrivals.

On Sundays the chief inspector remains in office to receive reports or boards arrivals bringing up near the station and requiring immediate attention.

On Monday the Chief Inspector attends at once to particular vessels entering dock, *e.g.*, passenger steamers with emigrants due that day. He overlooks the general work of the assistants, directs the crew of the launch, makes periodical examination of the launch, sees to her cleansing, repairs, stores, &c., checks accounts

[1] *Public Health*, vol. i. p. 26.

and forwards them to the central office; reports on moorings, safety and repairs of the hospitals; attends meetings of the authority. It is also his duty to carry on the correspondence of his office, to keep and periodically present to the Medical Officer of Health for examination and signature, an official log; to make, and direct the assistant inspectors to make, observations as to smoke and other nuisances, to keep a list of owners of steam-craft on the river, to examine cattle boats and vessels with perishable cargoes, the closet accommodation, cleanliness, lighting, ventilation, cubic space, water, provisions, &c., of ships; to inspect periodically the gangways and conveniences abutting on the port, to keep a record of all emigrants passing through the port, and under the direction of the Medical Officer of Health, to advise the Medical Officers of Health of other British ports of the same; to meet the Medical Officers with the launch as required; to attend to the posting or distributing of notices, inform the Customs of any vessels due and suspected of having infectious sickness on board; to make preliminary inquiry into sickness reported on shipboard; and except in ailment of unmistakably non-infectious character to notify to the Medical Officer or Assistant Medical Officer. . . . . . Each assistant inspector comes on duty at 9 A.M. on alternate mornings and remains on duty 24 hours. He examines the list of arrivals, receives the instructions of the Chief Inspector as to which dock he shall visit, &c., inspects vessels, and reports sickness noted on returning to office about 1 P.M. In the afternoon visits a different dock, or inspects on the river as required, returning to station at 7.30 P.M., meets quarantine boat at North Shields and extracts list of arrivals since 1.30 P.M. from sheets in water-guard office, deals with or reports on matters requiring attention, boards vessels about which he has particular instructions, returning to station about 8.40 P.M. and leaving again to catch 9.45 P.M. ferry, and meet quarantine boat at North Shields, returning to station at 10.40 P.M., where he remains at liberty to rest on the office couch, but ready for a call at any moment. Turns out again at 5.30 A.M. to meet quarantine boat at North Shields returning to station, crosses again at 8 A.M. for arrivals up to that hour, and returning to station is relieved by the other assistant inspector at 9 A.M. The time spent in the office is occupied in entering up inspection book, log book (which

each signs at the end of his watch) and homeward-bound register, particulars from *Shipping Gazette*, &c.

In the long days and when fishing craft are at the fish quay, North Shields, the Assistant Inspector on duty devotes from two to three hours before 8 A.M. inspecting these vessels.

The assistants as they go about their duties are instructed to make observations as to nuisances, &c., and to inquire of the Customs officials, dock police, and others for information as to anything requiring their interference.

(445) *Duties of Inspectors as laid down by order of the Local Government Board.*

1. He shall perform either under the special directions of the sanitary authority, or (so far as authorized by the sanitary authority) under the directions of the Medical Officer of Health, or in cases where no such directions are required, without such directions, all the duties specially imposed upon an inspector of nuisances by the Sanitary Acts or by the orders of the Local Government Board.

2. He shall attend all meetings of the sanitary authority when so required.

3. He shall by inspection of the district, both systematically at certain periods, and at intervals as occasion may require, keep himself informed in respect of the nuisances existing therein that require abatement under the Sanitary Acts.

4. On receiving notice of the existence of any nuisance within the district, or of the breach of any bye-laws or regulations made by the sanitary authority for the suppression of nuisances, he shall, as early as practicable, visit the spot, and inquire into such alleged nuisance or breach of bye-laws and regulations.

5. He shall report to the sanitary authority any noxious or offensive businesses, trades, or manufactories established within the district, and the breach or non-observance of any bye-laws or regulations made in respect of the same.

6. He shall report to the sanitary authority any damage done to any works of water supply or other works belonging to them, and also any case of wilful or negligent waste of water supplied by them, or any fouling by gas, filth, or otherwise of water used for domestic purposes.

7. He shall from time to time, and forthwith upon complaint, visit and inspect the shops and places kept or used for the sale of butchers' meat, poultry, fish, fruit, vegetables, corn, bread, or flour, or as a slaughter-house, and examine any animal, carcase, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, or flour which may be therein; and in case any such article appear to him to be intended for the food of man and to be unfit for such food, he shall cause the same to be seized, and take such other proceedings as may be necessary in order to have the same dealt with by a justice; provided that in any case of doubt arising under this clause he shall report the matter to the Medical Officer of Health, with the view of obtaining his advice thereon.

8. He shall, when and as directed by the sanitary authority, procure and submit samples of food or drink and drugs suspected to be adulterated, to be analyzed by the analyst appointed under the Sale of Food and Drugs Act, 1875, and upon receiving a certificate stating that the articles of food or drink or drugs are adulterated, cause a complaint to be made and take the other proceedings prescribed by that Act.

9. He shall give immediate notice to the Medical Officer of Health of the occurrence within his district of any contagious, infectious, or epidemic disease of a dangerous character, and whenever it appears to him that the intervention of such officer is necessary in consequence of the existence of any nuisance injurious to health, or of any overcrowding in a house, he shall forthwith inform the Medical Officer thereof.

10. He shall, subject in all respects to the sanitary authority, attend to the instructions of the Medical Officer of Health with respect to any measures which may

be lawfully undertaken by him under the Sanitary Acts for preventing the spread of any contagious, infectious, or epidemic disease of a dangerous character.

11. He shall enter from day to day, in a book to be provided by the sanitary authority, particulars of his inspections and of the action taken by him in the execution of his duties. He shall also keep a book or books, to be provided by the sanitary authority, so arranged as to form, as far as possible, a continuous record of the sanitary condition of each of the premises in respect of which any action has been taken under the Sanitary Acts, and shall keep any other systematic records that the sanitary authority may require.

12. He shall at all reasonable times when applied to by the Medical Officer of Health, produce to him his books or any of them, and render to him such information as he may be able to furnish with respect to any matter to which the duties of inspector of nuisances relate.

13. He shall, if directed by the sanitary authority to do so, superintend and see to the due execution of all works which may be undertaken under their direction for the suppression or removal of nuisances within the district.

14. In matters not specifically provided for in this order, he shall observe and execute all the lawful orders and directions of the sanitary authority, and the orders which the Local Government Board may hereafter issue applicable to his office.

SECTION XII.

INSPECTION OF FOOD.

CHAPTER XXXVI.

THE INSPECTION AND SEIZURE OF UNWHOLESOME FOOD.

(446) *Powers of Inspecting Food.*

UNDER the 116-119th sections of the Public Health Act in the country generally and in the Metropolis under the Nuisance Removal Acts, 1855, s. 26, and 1863 s. 2, 3, and the Sanitary Amendment Act 1874, s. 54, 55[1] medical officers of health or inspectors of nuisances have pretty extensive powers of inspecting at " all *reasonable* times," any animal, carcase, meat, poultry, game, flesh, fish, fruit, vegetables, corn, bread, flour or milk exposed for sale, or deposited in any place for the purpose of sale, or of preparation for sale, and intended for the food of man—the burden of proof always resting on the party charged, of showing that the meat, &c., was not deposited for sale; if any of the substances mentioned appear " diseased or unsound or unwholesome, or unfit for the food of man, he may seize and carry away the same himself or by an assistant, in order to have the same dealt with by a justice." It is the magistrate's duty, if he consider the case proved, to order the food to be destroyed, or so disposed of as to prevent it being sold or used as food for man, while the offender may be fined up to £20, or imprisoned up to three months. A warrant to search premises may be also obtained from a justice on complaint made on oath by a medical officer of health or by an inspector of nuisances. By the Horseflesh Act 52 and 53 Vict. c. 11, similar powers as to inspection, examination, and seizure are given of horseflesh sold for human food and not legibly labelled horseflesh.

[1] In Scotland, under the Public Health Act (Scotland), s. 26.

Some articles of food, such for example as eggs, do not seem to be included in the list. The words are general enough to embrace all conditions of the foods mentioned which may render them unsuitable for use, such for example as incipient decomposition in all its forms up to putridity, mouldiness, the bruising of fruit, the mustiness of flour, the admixture of dirt, and also such diseases of corn as ergot; the words also embrace every species of disease which may be assumed as injurious, and in the author's opinion milk or other similar substances which can be proved to have been exposed under conditions which render it probable that the germs of infectious disease may have been absorbed come also under the section.

In a police-court case at Maidstone, it was proved that children peeling after scarlet fever were allowed to pick currants, and that such currants were sent to the London market; the justices refused to convict under the Public Health Act, a decision probably wrong, and one which would not be upheld by a superior court.

CHAPTER XXXVII.

POISONOUS FOOD.

(447) *The Development of Poison in Food.*

CASES occur from time to time in which after partaking of some article of food, the person is seized with illness, which most frequently takes the form of intestinal irritation, and may indeed lead to death. Of the different kinds of butchers' meat, pork is accredited with by far the greater number of cases, but beef, veal, and mixtures such as sausages, brawn, and meat pies, have all given rise to symptoms of poisoning, and careful chemical investigation have shown that all ordinary vegetable and mineral poisons have been absent.

The cases may be divided into two classes—viz., one class in which it would seem probable that a saprophytic micro-organism has split up the albumen of the meat and produced a poisonous substance, as for example tyro-toxicon; another class which is more obscure, but a theoretical explanation may be suggested—viz., that the meat was derived from a diseased animal, in the flesh of which were one or more ptomaines produced during life and not decomposed or altered by cooking.

(448) *Pork-Pie Poisoning at Retford.*

One of the best examples of the first class is the pork-pie and brawn poisoning at Retford investigated by Mr. Spear.[1] The material that was proved to have caused 70 cases of illness of varying severity and one death was derived from a pig, the sixth

[1] *Supplement to the Seventeenth Rep. Loc. Gov. Board.*

survivor of a litter of seven which had come into the Retford Co-operative Society's possession in April, 1887. For six weeks before its slaughter, it was fed entirely on meal, and to all appearances was a perfectly healthy pig; it was slaughtered on the 8th of November; 50 lbs. of the pork were handed over to the baker to make pork pies and brawn; a leg and two sides were found in salt at the stores when Mr. Page made his inquiries, the remainder (about three stone) had been sold as fresh pork between the 9th and 12th of the month; no case of illness could be discovered from the consumption of the pork in its fresh state, but from that made into pie and brawn the outbreak was entirely traced, the majority of those consuming it suffering from diarrhœa and other symptoms of gastro-enteritis.

The pies and brawn were made and cooked on the 10th of November, the temperature of the oven being 220°F., or above, and they were purchased by various families and consumed, from about the 13th to the 17th. Presuming, then, that the meat was properly sterilized by cooking, it must have attained its noxious qualities in about 48 hours. There was some evidence that of the few persons who ate the brawn on the 11th, that is the day after cooking, a minority only of these became affected, while after the 11th a majority of those who consumed either the brawn or pies became ill.

Dr. Klein submitted the pie and brawn to a microscopical and bacteriological examination. On opening the pie there was observed in its depths a wide crack in which was a continuous layer of a greyish brown viscid scum. This scum was made almost entirely of minute thick rods rounded at the ends, constricted in the middle, and in many places arranged in long chains. The single or dumb-bell rods were mobile, those in chains quiescent. There were also present micrococci in small groups or zooglœa, and a few yeast cells. The micrococci were cultivated and proved not to be pathogenic. The minute thick bacillus was cultivated and found to grow freely at a temperature of 38°C., which is one of the distinctions laid down by Dr. Klein to differentiate it from a bacillus of similar form in connection with a veal-pie poisoning investigated by him on a previous occasion. The rods are mobile 8μ to $1·2\mu$ in length, about $·5\mu$ in thickness, many of them constricted in the middle, forming a sort of

dumb-bell. Cultivated on alkaline nutritive gelatin in streak cultivation at 20°, in 24 hours there is a whitish continuous line like a line of white paint; after 24 hours a distinct blue colour appears in the gelatin immediately in contact with the streak, becoming more gradually diffused into the depth.

In broth also after about ten days at 35° the liquid becomes slightly greenish. Twelve mice fed directly with the pie, became very ill, one of the twelve died. Two dogs were fed with the pie but the effect was but little evident. Mice were also fed with the cultures and suffered from the same kind of illness, some of the mice dying, those that died showed the same post-mortem signs, viz. congestion of stomach and intestines, and enlargement of spleen, kidneys and liver. The remarkable fact was discovered that cultures from ten days to a fortnight old had no effect on mice.

(449) *The Arlford Sausage Poisoning Case.*

As an example of the other type of meat poisoning may be cited the Arlford [1] sausage poisoning case investigated and described by Dr. Ballard. In this case a gardener aged forty-two purchased in Chester half a pound of sausage. At about 11 A.M. the same morning he ate the sausage, and in three-quarters of an hour was found extremely ill with choleraic symptoms; the man died after a week's illness, pneumonia apparently supervening, but there was no post-mortem examination.

The sausage eaten was part of a consignment of American manufacture; on the man's illness being discovered, the rest was put aside, portions of the sausages being experimented on by Dr. Klein. Some were found to be innocuous, others very poisonous to small animals such as mice and rabbits. "In all instances where the animals became ill, the illness showed itself soon after the feeding, viz. from a quarter of an hour to a few hours. The animals became quiet, and in some instances, especially in the rabbits, there was vomiting a quarter of an hour after feeding; they neither cared to take food, nor to move; their faces were pinched and their eyes small. In the case of the mice their coats became very rough. This state soon grew worse, the animals becoming comatose, the temperature rapidly sank and

[1] *Supplement to the Eleventh Annual Rep. of the Loc. Gov. Board.*

the animals soon died. In some cases they lingered on for several days, recovered slightly, took food again and became a little more lively; but when killed they showed the same post-mortem appearances as those that died spontaneously, only in a milder degree. On post-mortem examination, the appearances found were hæmorrhages in the stomach, congestion of the lungs, enlarged kidneys, the cortex of the organs being pale, the medulla hyperæmic. On microscopical examination of the kidney, the important fact was ascertained that most of the urinary tubules contained casts, that many Malpighian corpuscles and the tissues surrounding them were in a state of disintegration, without however there being present any inflammatory cells (pus corpuscles), so that this disintegration was evidently the direct result of some destructive agency circulating in the vessels of the glomeruli of the Malpighian corpuscles." In this case there was evidently some soluble poison, probably of bacterial origin.

The student may also refer to the instructive cases of poisoning by meat at Welbeck and at Nottingham, both investigated by Dr. Ballard,[1] the symptoms of which somewhat differed from the above in being more like a specific (typhoid) fever.

(450) *Diarrhœa from Milk or Cheese—Tyro-toxicon.*

In cases in which it seems likely that either milk or cheese has produced intestinal disturbance, carefully examine for diazo-benzene butyrate, also named tyro-toxicon, a very poisonous substance which is formed with considerable ease. If, for instance, a minute fragment of butyric ferment be added to milk in a bottle and the bottle corked up, tyro-toxicon is formed. The testing for tyro-toxicon is a simple matter :—supposing the substance is milk, a sufficient quantity of carbonate of soda is added to give a decided alkaline reaction, and then the liquid is shaken up with an equal bulk of ether ; this operation is best done in a tube with a stopcock at the bottom. The tube is allowed to stand until the ether rises to the top ; if there is no proper separation a little strong alcohol will assist matters by clearing the liquid up ; the milk is now run off and the ethereal layer separated. The ether is poured into a flat dish or saucer and allowed to evaporate

[1] *Supplement to the Tenth Annual Rep. of the Loc. Gov. Board.*

spontaneously; the residue left on evaporation is dissolved in a little water and filtered through wet filter paper to free it from fat and again the filtrate shaken up with ether, the ethereal layer is once more allowed to evaporate spontaneously; the residue contains any tyro-toxicon present in a sufficiently pure state to admit of tests being applied. The most convenient test is a mixture of equal bulks of pure phenol and sulphuric acid. This strikes an orange red or purple colour with very small quantities of tyro-toxicon. Another test is to evaporate the solution to dryness with strong potash; a compound is formed soluble in alcohol but which is precipitated by ether in the form of crystals.

If cheese is to be tested the cheese is triturated with water and carbonate of soda added, and the solution or emulsion shaken up as before with ether.

(451) *Method of Investigating outbreaks of Diarrhœa or Illness supposed to result from bad Food.*

In these investigations it will be far simpler and more certain to pursue a properly thought-out plan of investigation than go haphazard to work. The only way is to examine each person separately as to what he or she has eaten for one, two, or three days previously, bearing in mind that it is of equal importance to examine those who have not suffered, as well as those who have suffered. The inquirer will find it convenient to draw out the facts in a tabular form according to the plan drawn out below, putting a simple mark / against the particular article eaten on each day, and denoting by a single stroke that the substance has been eaten sparingly, a double stroke thus × that it has been eaten or drunk in fair quantities and a treble stroke thus ⋇ that it has been taken in large quantities.

The table on the following page gives at a glance much information: for instance, take the dairy products—it is obvious that not alone did every one of the family use milk but the boy drank it largely and we will presume unboiled; the milk may therefore be excluded in the same way the butter is excluded; on the other hand the master and mistress both eat Gorgonzola cheese and both suffered, but this fact is neutralized by the fact that two others who did not eat this cheese were also ill; hence it can hardly be

TABLE LIII.

	Mr. D. 45. Ill. W.						Mrs. D. 43. Ill. T.						Miss D. 12. Ill. W.					Master D. 10. Not Ill.						Domestic. No. 1 Not Ill.					Domestic. No. 2. Ill. W.				
	F.	S.	𝔖.	M.	T.	W.	F.	S	𝔖.	M.	T.	W.	F.	S.	𝔖.	M.	T.	F.	S.	𝔖.	M.	T.	W.	F.	S.	𝔖.	M.	T.	F.	S.	𝔖.	M.	T.
CONDIMENTS.																																	
Salt	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
Pepper	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	...	...	...	...	...	...	/	/	/	/	/	/	/	/	/	/
Worcester sauce	/	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	/									
Cayenne	/																																
DAIRY PRODUCTS.																																	
Milk	/	/	/	/	/	/	/	/	/	/	/	/	×	×	×	×	×	×	×	×	×	×	×	/	/	/	/	/	/	/	/	/	/
Butter, fresh	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/										
,, salt	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	/	/	/	/	/	/	/	/	/	/
Cheese, Gorgonzola	/	/	/	/	/	/	/	/	/	/	/	/																					
,, American	.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	/	/	/	/	/	/	/	/	/	/
VEGETABLES.																																	
Potatoes	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
Carrots	...	...	/	...	...	...	...	/	...	...	...	...	...	/	...	...	...	...	/	...	...	.	...	...	/	...	...	...	...	/			
Parsnips	...	...	...	/	...	...	...	...	/	...	...	...	...	...	/	...	...	...	...	/	...	.	...	...	...	/	...	...	...	...	/		
Haricot beans	/	...	...	...	...	...	/	...	...	...	...	...	/	...	...	...	...	...	...	...	...	...	...	.	...	...	...	...	/				
Bread, cottage (household)	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
Madeira cake	...	...	...	...	...	...	...	...	...	...	...	...	...	/	...	/	...	...	...	/	...	/											
MEATS.																																	
Pork	...	...	.	...	×	...	...	...	...	...	×	...	...	...	...	/	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×
Beef	...	...	/	/	...	...	...	...	/	/	...	...	...	...	/	/	...	...	...	...	...	/	...	...	...	/	/	...	...	...	/	/	
Mutton	/	/	...	...	...	...	/	/	...	...	...	...	/	/	...	...	...	...	/	...	...	...	...	/	/	...	...	...	/	...	/		
FRUITS.																																	
Apples	...	...	...	...	...	...	...	...	...	...	...	...	/	/	/	/	...	/	/	/	/	×											
Bananas	...	...	...	...	...	...	...	...	...	...	...	...	...	...	/	/	...	...	...	...	/	×											

the cheese; and proceeding in this way with each item, there is one substance found—the pork—which the sufferers took alone and no one else, hence when this stage is arrived at the attention may be concentrated to this particular article, and strict inquiry made concerning it—that is, where it was bought, and so forth; it may then be possible to find out whether any other families have had pork from this particular animal or not, or bought pork the same day from the same butcher. In this way ultimately the evil may be traced back to its source. In such work as this he who is capable of taking the most trouble will be most likely to succeed. An apparently simple inquiry consumes much time and demands the exercise of natural powers of observation and keenness that some persons are never able to acquire.

CHAPTER XXXVIII.

UNFIT VEGETABLE SUBSTANCES.

(452) *Decomposed Vegetables.*

No special details need be here given upon the appearances which vegetable substances present when partially or completely decomposed; all persons of ordinary intelligence can distinguish between fresh and stale vegetables. On the other hand, differences of opinion will occur with regard to fruit; if fruit such as apricots, strawberries, gooseberries are but partially decomposed, it is doubtful whether it is fair to seize and destroy them, because the condition is so evident that the public are not defrauded, and bruised and partially mouldy fruit is often sold for making preserve at a low price. Hence in these cases the medical officer must be entirely guided by the extent of the decomposition or condition, and the Author's advice is only to act in those cases of a decided character.

(453) *Unhealthy condition of Flour or Bread.*

Flour may be simply musty; here again, unless the mustiness is pronounced, it will not be wise to condemn as unfit for food. If it smells only faintly such flour will make fairly eatable bread; on the other hand, flour with evident and strongly smelling mustiness should be unhesitatingly condemned.

(454) *Ergot in Flour.*

Since ergot causes a special malady, there can be no possible difference of opinion that ergotised flour if discovered should be unhesitatingly condemned. Such flour is dark in colour and has a peculiar odour. Examined by the microscope the little dark masses of ergot may be seen; if also the flour be stained by aniline

blue, all starch granules damaged by ergot, or as for that by any other fungus, will be stained intensely. A portion of the flour may be exhausted by boiling strong alcohol, the alcoholic solution acidified by dilute sulphuric acid and examined by the spectroscope. If the flour is ergotised, the solution will be more or less red and show in dilute solution two absorption bands, one lying in the green near *e* and a broader and stronger band in the blue between *f* and *g*. On mixing the original solution with twice its volume of water and shaking up with ether or amyl alcohol, or benzine or chloroform, if ergot be present any of these solvents become of a red colour.

(455) *Corn Cockle Seeds in Flour.*

A mixture of these seeds with flour will make the flour unfit for use, the active principle of the *Agrostemma* or *lychnis cithago* being saponin, a glucoside with marked irritant properties. The seeds are in shape not unlike a rolled up caterpillar, the surface being beset with little warty projections arranged in rows. The surface of the testa, or seed covering, shows, when examined by the microscope, very large thickened cells ·1 to ·6 mm. diameter, forming on the surface branching tubercles, beneath which is a loose parenchyma made up of two layers or rows of simple cells; this rests on a thin epithelial membrane composed of flat cells, most of which exhibit a peculiar striation; next to this comes the main substance of the seed, the endosperm, composed of ordinary large-celled parenchyma, filled with very minute starch granules; and lastly, there is the embryo, the structure of which cannot be distinguished from the embryo of other seeds. There are little bodies scattered among the endosperm, consisting of egg or spindle-shaped finely granulated grains, from ·02 to ·1 mm. in long diameter, consisting wholly of saponin, starch, and mucin; these bodies are not peculiar to corn cockle seeds, but occur in other plants of the same natural order—that is, in the clove-worts. F. Beneke has examined the sizes in various plants and gives the maximum as follows:—spergula ·030 mm., beta ·057 mm., spinacia ·64 mm., agrostemma ·122 mm., hence over ·07 mm. points to corn cockle. Flour containing corn cockle seeds yields a larger percentage of oil to ether, and the ether extract has an acrid taste and is of a pronounced yellow colour.

CHAPTER XXXIX.

INSPECTION OF FISH AND MEAT.

(456) *Inspection of Fish.*

Fish are subject to various parasitic diseases, but the purpose of inspection will be mainly to ascertain whether the fish are stale or fresh. Since a large proportion of both inspectors and medical officers have at one time or another of their lives been amateur fishermen, they will probably know perfectly well the signs of a fresh fish, the bright prominent eye,[1] the healthy gills, the peculiar feel of the whole body and the absence of odour when the mouth and gills are opened and the inspector's nose applied close. In a dark place fish beginning to decompose will also here and there shine with a phosphorescence, but before this takes place an odour will nearly always be detected. The slightest taint in fish renders them unfit for use and justifies condemnation.

(457) *Inspection of Meat.*

Since it is only possible in a minority of cases to tell from a

[1] One of the best descriptions of the dodges of fishermen is to be found in Blackmore's novel, *The Maid of Sker.* "I felt that I could trust nobody to have proper faith, especially when they might behold the eyes of the fish retire a little, as they are apt to do when too many cooks have looked at them. . . . . When the eyes of a fish begin to fail him through long retirement from the water, you may strengthen his mode of regarding the world (and therefore the world's regard for him) by a delicate bit of handling. Keep a ray fish always ready—it does not matter how stale he is—and on the same day on which you are going to sell your bass, or mullet, or cod, or whatever it may be, pull a few sharp spines, as clear as you can, out of this good ray. Then open the mouth of your languid fish and embolden the aspect of either eye by fetching it up from despondency with a skewer of proper length extending from one ball to the other. It is almost sure to drop out in the cooking, and even if it fails to do so none will be the wiser, but take it for a provision of nature—as indeed it ought to be."

look at the muscles or flesh of a slaughtered animal whether it was in good health or the reverse, the medical officer should aim at inspecting the entire carcase.

It does not admit of two opinions that, knowing what we do of the importance of a healthy meat supply, the time has come to insist upon a proper inspection of meat; this proper inspection can only be made if in each town the slaughtering is centralized; it is to be hoped that ultimately such meat inspection will occupy the whole time of one or more pathologists who should have every appliance for the microscopical examination and also for bacteriological research.

A medical officer of health is expected by the law to give a glance at a leg of mutton, or a piece of beef, to detect there and then the seeds of disease and to at once convey it before a magistrate. Hence as this is an impossibility, the work is either not done at all, or the inspection is only made of absolutely putrid pieces of meat, or of cases concerning which special information has been given.

(458) *Characteristics of Good Meat.*

All fresh meat is acid to test paper; directly decomposition commences the acidity diminishes and then is replaced by an alkaline reaction. If a little meat is chopped up and warm water poured upon it, the odour should not be disagreeable; on the other hand, meat from a diseased animal has a sickly peculiar smell and occasionally it possesses a distinct odour of the medicine which the farrier has drenched the sick animal with. In this way sometimes aloes may be smelled. The colour of the meat should be normal; each animal's meat has a colour of its own, the peculiar pale tint of veal or of mutton, and the deep red of beef are examples; any marked deviation from the colour is a suspicious sign. Calves, sheep, and pigs, being freely bled to death, should the meat of these animals have an abnormal red hue it may be a sign that they were not killed in the usual manner and therefore this will again be suspicious.

Meat which is sodden and contains much water is not unfrequently diseased.

To examine meat practically a knife should be run into it, well

into the centre of the mass, and the knife carefully smelled on withdrawal; if opportunity admits a portion of the suspected meat may be examined by the microscope.

A portion may also be soaked in distilled water and a little litmus added so as to test its reaction.

To detect trichinæ see page 629.

(459) *The Detection of Tubercle Bacilli.*

To detect tubercle bacilli in meat it will be necessary to very carefully dissect out any little portion which looks suspicious; cut fine sections of it and stain the sections with Gibbes' double stain.

Gibbes' double stain is made by dissolving 2 parts of rosaniline hydrochlorate, 1 of methylene blue, in 3 parts of aniline oil, and 15 parts of rectified alcohol; lastly dilute with 15 parts of water.

The sections are soaked in this solution first made very hot for several hours, the excess of stain is washed away with methylated spirit; the sections are dried and mounted in Canada balsam. The search for tubercle bacilli must be made with a high power and with good illumination.

Muscular tissue may contain the germs of tubercle and yet the most experienced microscopist fail to detect them, but by injecting the flesh juice into guinea-pigs their presence may yet be shown—*e.g.*: At Munchen some experiments have been made recently by Steinheil[1] as to the possibility of infecting guinea-pigs with the products from the muscles of persons affected with phthisis. The material used was portions of the psoas muscles of nine patients who died of phthisis. The muscle was cut up into very fine pieces, and submitted to the pressure of a screw press. The juice obtained was injected into guinea-pigs. Of eighteen guinea-pigs thus treated fifteen died of tuberculosis, although no tubercle could be detected in the muscles so used. Steinheil draws the conclusion that the muscular flesh in advanced human phthisis is infectious as a rule; hence the possibility that the flesh of animals affected with bovine tuberculosis is dangerous cannot be denied.

[1] *Munchen med. Wochenschrift*, 1889, Nos. 40 and 41.

This method is unfortunately not open at present to English medical officers of health, being a breach of the Vivisection Act. It is only in those large towns and places where the local authority possesses an ice chamber in which to deposit suspected meat that any prolonged investigation can take place ; the officer has usually to decide there and then ; whereas in common justice to all parties it would be better for there to be a proper place for the meat to be taken to and there detained and a thorough and complete examination to be made.

CHAPTER XL.

DISEASES OF ANIMALS RENDERING THEIR FLESH MORE OR LESS UNFIT FOR FOOD.

(460) *Measles in the Pig and the Ox.*

THIS is a parasitic disease, little cysts being scattered about the muscular system, each cyst containing the larval or hydatid stage of a tape-worm. The parasite is called the bladder-worm, or *cysticercus cellulosæ.* A different species affects the pig to that of the ox, but the naked eye appearances and the distribution in each is very similar. The way in which these parasites gain access to animals is as follows :—A human being afflicted with tape-worm passes the segments of the mature tape-worm full of thousands of eggs. These eggs are in some way or other swallowed by pigs or oxen (or, as for that, by sheep), the eggs are hatched inside the body. The embryo when hatched makes its way into the tissues by the aid of a peculiar apparatus round its mouth consisting of six hooklets, and there develops not into a tape-worm but into the hydatid or bladder form. Nor will it further develop, save the animal is killed and the living hydatid pass into the human or other intestine, then it enters on its completed existence, and fastening by means of the hooklets, or in the hookless form by suckers, on to the mucous membrane, grows into a tape-worm many feet in length. Each joint of a tape-worm may contain as many as 53,000 eggs, so that if only a few joints of the tape-worm are eaten, and only a portion of the eggs hatched yet enormous numbers of hydatids may be formed. When the embryo arrives at its resting-place a cyst or bladder forms at the spot, in the centre of which the worm is coiled up; it is about

PLATE VI.

R. & R. Clark, Edinburgh

a third of an inch in its longest diameter, or from the size of a pea to that of a cherry in the retracted state, it is oval, but when the head and neck is extended it is bottle or gourd-shaped. The vesicle is filled with an albuminous, milky-coloured fluid, and in the retracted state exhibits a dense white spot at one point of its surface. Hydatids in pigs are specially to be looked for in the muscles of the tongue, the neck, and the shoulders; but hydatids may be found in the liver, kidney, brain, and many tissues in the body. During life the existence of measles is often detected, the pig is thrown down, a piece of wood is thrust across the jaws, and the tongue pulled outside the mouth, the organ is carefully examined underneath towards the root and the bridle where, if present, the cysts may be seen and felt, still their absence is not conclusive evidence that they do not exist elsewhere.

In the ox, the hydatid is to be looked for in the same situations as in the pig.

The naked eye appearances of measles (*cysticercus bovis*) in beef are represented in Plate VI., which has been drawn (natural size) from a specimen in the College of Surgeons' Museum (No. 123 in Catalogue). This cysticercus if taken into the human intestine may develop into the tape-worm known as the *tænia medio-cannelata*; neither the bladder- nor the tape-form are provided with hooks.

The diaphragm, the tongue, the superficial muscles of the shoulder, breast, loin, hip, or quarter, and the eyelids, are the special likely places. The heart, too, in the majority of cases is also affected.

Hydatids have a considerable power of resistance to both heat and cold, but they perish at a temperature of 170° F., and, of course, at the temperature of boiling water, so also a lengthened exposure to cold, or smoking will destroy them, and prolonged immersion in brine. Nevertheless, it is not safe to allow any measly meat to be sold, for it is never certain that such meat will be cooked properly, and the signs of death in such low animal forms are deceptive.

(461) *Trichinæ—Trichinosis.*

The *trichina spiralis* is a minute worm, parasitic in the muscular system of man and animals. The disease affects pigs and men,

but neither oxen nor sheep. The pigs become trichinous from eating offal,[1] man becomes trichinous from eating pork or bacon or ham derived from a trichinous pig.

The male worm is only $\frac{1}{18}$ inch when fully developed, the female is longer, the length being $\frac{1}{8}$ inch; the body is rounded and thread-like, the head is narrow, finely pointed, unarmed, with a simple central small mouth opening; the posterior extremity of the male is furnished with a bilobal caudal appendage, the anal aperture being situated between these divergent appendages; the penis consists of a single spicula cleft above, so as to assume a V-shaped outline. The female has the genital outlet placed far forward, at about the end of the first fifth of the long diameter of the body; the eggs measure in their long diameter $\frac{1}{1270}$ inch, these are hatched in the body of the parent; the reproduction is therefore viviparous.

The females contain mostly from 500 to 600 eggs. The newborn young being hatched, commence their wandering. They penetrate the wall of the intestines and pass into the muscles, proceeding in the course of the intermuscular connective tissue. It is specially those muscles which are nearest to the cavity of the abdomen in which the majority of the trichina are found. It takes about fourteen days for the embryos to attain the full growth. Soon after the introduction of the parasite into the muscle, the infested muscular bundle loses its structure, and at the spot where the worm coils itself up a lemon-shaped or globular little cyst is developed. In this cyst there may be from one to three trichinæ. The cyst often becomes calcified.

During this migration the individual affected suffers from pains in the limbs, and often swelling about the joints with fever; there is also often diarrhœa and peritonitis. The disease is likely to be confused with rheumatism, rheumatic fever, tuberculosis, enteric fever, and pyæmia. If a considerable quantity of trichinous meat is consumed, the embryo may be produced in prodigious numbers and the results are then likely to be fatal. In 1863, out of 103 persons who ate sausages made of an affected pig, at Hettstadt, eighty-three died from trichinosis, and there are several similar cases on record. In 1873, 250 persons suffered from trichinosis at Magdeburg, Germany. Many died and most were seriously ill.

[1] It has been suggested that rats are also a source of trichinæ.

PLATE VII

F. & P. Clark, Edinburgh.

Bits of muscle removed by a trocar from some of the sufferers and weighing about a gramme were found to contain as many as 800 trichinæ. The symptoms produced are not usually immediate but follow after from five to six days.

It is not known how many pigs in this country are affected with trichinosis.

In America the Massachusetts State Board of Health have from time to time published the results of their supervision over the meat supply; thus in 1879 Dr. F. S. Billings examined 2,701 hogs, 154, or 5·7 per cent. were trichinous; in 1881 6,068 hogs were examined, 191 or 3·15 per cent. were trichinous. Professor E. L. Mark gives a return of careful examination of hogs raised near Boston, from which it appears during the period 1883–1888, out of 3,064 hogs 394 or 12·86 per cent. were found trichinous.

(462) *Examination of Meat for Trichinæ.*

The best part to search for trichinæ is the diaphragm, 25 per cent. of the total worms being found in that large muscle; after the diaphragm come the muscles of the shoulder and those of the loins but in a hog thoroughly infested, there is no muscle in which they may not be found, provided trouble is taken; the muscles of the back are those least affected.

A low power is only necessary (30 to 40 diameters), little bits of the muscle are teased out with needles and placed, after flattening out by the cover-glass, and adding a little glycerin, in the field of the microscope. Non-encysted trichinæ may be readily discovered in this way, on the other hand those that are encysted require special treatment; if the cyst is calcified a little hydrochloric acid will soon clear it up, the muscular substance may also be disintegrated by potash, which will not affect the cyst, but on the contrary render it more visible. By adopting such processes there should be no difficulty in identifying the worm if present. Plate VII. represents (natural size) a specimen of muscle from the human subject containing encysted trichinæ (Royal College of Surgeons' Museum). Professor Mark [1] takes nine slips of meat from the pillar of the diaphragm, and if no trichinæ is found in any one of

[1] *Twentieth Report of the Massach. State Board of Health.*

the nine samples the hog is passed as non-trichinous. He states that in several instances trichinæ were only detected in the eighth or ninth slip examined.

(463) *Vitality of Trichinæ.*

Trichinæ when encysted, have considerable tenacity of life. Müller found, for example, that trichinous flesh steeped in strong brine for 8-10 days was still able to infect rabbits. Trichinæ will withstand drying in the air or sun, and will live in putrified meat, but meat which has been boiled or roasted thoroughly experiment has shown is perfectly safe, but as trichinæ are not killed by a temperature of 122° F., the meat may still infect if the interior of the joint has not been brought to a sufficiently high temperature.

(464) *Glanders and Farcy.*

Horseflesh derived from a glandered horse is decidedly unfit for human food, although sold under its proper appellation "horseflesh." Glanders is a micro-parasitic disease affecting the horse, and which may be transmitted to man and cattle by inoculation. It is associated with a special bacillus the size of the tubercle bacillus. The disease is especially characterized by nodules and ulcers in the mucous membrane of the nose, the lymphatics also become affected, and nodules form in the internal organs, that is the lung, spleen, and liver.

(465) *Variola of Sheep.*

Variola or small-pox of sheep is an eruptive malady analogous but not identical with the small-pox of the human subject. There is a definite eruption which proceeds from red points to nodules, and then becomes pustular, the pustules ultimately break, then scab, the scab after a time becomes detached, leaving a cicatrix. The changes are chiefly in the skin, but also the mucous membranes of the nose and eyes are affected, the lymphatic glands are also inflamed. The flesh looks healthy, and apart from the skin the meat might be sold without detection. Variolous sheep are said to have been largely eaten in Paris at the time of the last siege of that city without injury. Nevertheless the meat of such animals should most decidedly be condemned.

PLATE VII

dinburgh

(466) *Pneumo-Enteritis of the Pig.*

This disease has been exhaustively investigated in a series of researches by Dr. Klein, see the 7th Annual Report of the Local Government Board (Supplement to Rep. of Medical Officer for 1877). It has been called a great variety of names, such as pig typhoid, hog cholera, malignant erysipelas, red soldier, purples, blue disease, and others. It has also been confused with splenic fever or anthrax. It is an infectious malady caused by special micro-organisms having considerable resemblance to the bacillus anthracis.

The disease is somewhat common in England, and causes when prevalent great losses to swine farmers.

In mild cases the skin is normal, but the inguinal glands are enlarged and red. The lymphatic glands of the pelvis are distinctly enlarged. So are also the mesenteric glands and the glands in the ligamentum gastro-hepaticum. Greater or smaller portions of these masses of lymph glands show redness of their cortical part, a redness due to hæmorrhage in the cortex of the gland.

The peritoneum is but slightly inflamed, but in the peritoneal cavity is a small quantity of fluid or solid lymph. The serous covering of the small and large intestine is hyperæmic.

In the mucous membranes of the intestines are very evident changes; that of the duodenum is intensely red, and on the crests of the folds are small hæmorrhages. The ilio-cæcal valve, the cæcum and colon, are also more or less congested, and very often there are minute hæmorrhages. There are always small ulcers on the ilio-cæcal valve, and a few also on the colon. Plate VIII. represents a portion of the mucous membrane of the ileum of a pig which had died of pig typhoid (Royal College of Surgeons' Museum). In the mild forms the colon and rectum are filled with normal fæcal matter. The lungs are usually congested, and many lobules in a more or less advanced stage of pneumonia. The bronchial glands are red and enlarged.

The muscular structure of the heart shows in most cases minute hæmorrhages, the same is to be said of the endocardium.

In the front part of the tongue on both upper and lower surfaces there are occasionally hæmorrhages.

In the severer cases all these pathological signs are much accentuated, and there are often patches of redness of the skin.

In the general muscular system no naked eye changes are to be seen, hence a single joint of pork derived from a pig, which has suffered or died from pneumo-enteritis, might be passed as good by any observer who had had no opportunity of investigating the internal organs.

In severe cases Klein states that the muscular tissue appears pale, soft, and moist, and on microscopic examination the muscular fibres are seen to be in a state of fatty degeneration. He further states that his assistants consumed without injury salt pork derived from carcases of pigs used in his experiments which had suffered from the mild attacks produced by inoculation.

In examining a pig's carcase for signs of pneumo-enteritis the most constant changes are the diseased condition of the lungs, the intestinal glands, and the congestion and ulceration of the lining membrane of the gut. If these are healthy the animal cannot have suffered from pneumo-enteritis. The liver, spleen, and kidneys in the milder forms are healthy, hence the normal condition of these organs must not be taken as evidence of previous good health. The bacillus associated with the disease is two to three μ long (but it is capable of growing to a great length), it is actively motile, which distinguishes it from anthrax. Spore formation has been observed. The bacilli can be cultivated in broth or hydrocele fluid. From artificial cultures the disease may be produced in pigs, mice and rabbits. The bacilli are not to be found in the blood or spleen, but may be found in the lung, in the sanguineous fluid of the trachea, in the peritoneal exudation, and in any purulent collection, such as abscesses at the seat of inoculation. So far as is known the disease is not transmissible to man.

(467) *Swine Plague.*

This is an affection of the digestive organs of which the large intestine is principally involved. The latter is as a rule the seat of diphtheria. At the same time the lymphatic glands are affected, and there may be observed traces of a general slight infection. The disease may be accompanied by slight lung affections.

(468) *St. Anthony's Fire.*

In this disease the symptoms cannot be differentiated from pyæmia or anthrax. The most important changes are bright

patchy redness of the skin, enlargement of the spleen, inflammation with minute hæmorrhages of the stomach and intestines, infiltration and congestion of the kidneys; there may also be purulent foci in the liver, but save in the worst cases the muscular system will show little if any alteration.

(469) *Foot and Mouth Disease.*

This is a disease often epizootic among cattle and sheep. The milk of affected cows will produce the same malady in man, and such milk should be destroyed. The essential features of the disease are the formation of blebs or blisters on the tongue, the lining membrane of the mouth, the udder of cows, and between the claws of the hoof; the blisters soon break and leave ulcers. The changes in the internal organs are of too general a nature or too slight in character to be pathognomic, so that unless the mouth, feet, and mucous membranes be inspected there will be but little chance of ascertaining whether a given animal has suffered from foot and mouth disease or not. A special micro-organism, a streptococcus, is associated with the disease, and has been found in the fluid of the vesicles and in the milk. The cocci occur singly, in dumb-bell, and in curved chains. They can be readily cultivated in the ordinary nutrient media, and do not liquefy the gelatin. The flesh of animals suffering from foot and mouth disease is said to be innocuous, but there have been few exact experiments, and it is safest to consider all animals affected with general diseases unfit for use as food.

(470) *Pleuro-Pneumonia.*

The pleuro-pneumonia of cattle is a very fatal and contagious disease; the post-mortem characters are confined to the organs of the chest, the lungs are deeply congested and enormously increased in weight, they sink in water, have lost their crepitant feel, are more or less œdematous, and when cut in two they have a marbled appearance, the pleura or lining membrane is adherent, being covered with a fibrinous layer, and there is more or less effusion. The cellular tissue between the chest wall and the pleura is seldom affected, and the butcher by removing the lungs and stripping off the pleura removes all traces of disease. The flesh, once the lungs

are removed, will look like ordinary flesh, save in cases of long duration, when of course the animal will be wasted. There is reasonable doubt whether the flesh of animals suffering from pleuro-pneumonia is hurtful; the existing evidence is rather to the effect that it has been consumed by large populations without injury. Nevertheless it should be an offence to sell the carcases of animals which have died from or suffered from this disease as if from a healthy animal.

From what has been said it is obvious that, save the organs of the chest be inspected, there is no chance of detecting the facts after death, although from noting that the pleura has been stripped off there may be a well grounded suspicion that something was wrong.

(471) *Cattle Plague.*

Cattle plague is occasionally epizootic in the British Islands. It is a highly contagious malady attended with diarrhœa, injection of the mucous membrane, and is accompanied by an eruption. The post-mortem signs in mild cases are not marked. There will be found congestion and ecchymoses in the gastro-intestinal mucous membrane, especially on the free borders of the mucous folds in the fourth compartment of the stomach and around the pylorus. In severe cases the alterations in the intestines and stomach are more profound. Not alone congestion of the entire surface but hæmorrhages, extravasations of blood and ulcers are to be seen. Sometimes there are extensive excoriations from the shedding of the epithelial layers of the mucous membrane. There is injection of the trachea and bronchi in the worst cases; here again the epithelial layer may have been shed, leaving excoriations. The lungs are often emphysematous, the heart is usually flabby and friable, the blood is dark coloured and coagulates imperfectly. The skin may be found in parts desquamating, in parts covered with pustules or papules. In mild cases the meat apart from the internal organs will not look different from any other meat, on the other hand in severe cases the meat itself will be dark coloured and the muscular tissues soft. There is no difference of opinion that animals which have died of cattle plague are unfit for human food.

PLATE IX

F. & P. Clark, Edinburgh.

(472) *Tuberculosis.*

Tuberculosis has been fully considered at page 462. The question as to whether an apparently local affection of the lung also affects the entire body has been now definitely answered in the affirmative, and the safest course is to consider tubercle always generalized, and to condemn the whole carcase for the slightest tuberculous taint; it would also be a just and sufficient ground to condemn any milk derived from a tuberculous cow or other animal as not fit for human food.

(473) *Actinomycosis.*

This is a somewhat common disease of cattle, and occasionally it has been found to be a cause of disease and death to man. Possibly it is more common both in animals and men than is believed, for the symptoms during life and the appearances after death may be readily mistaken for local and generalized tuberculosis or for those of septicæmia.

The disease is caused by the "ray fungus" (actinomyces); this (see Fig. 54) parasite forms rosettes of club-shaped elements. They may be seen as little white or yellowish specks by the unaided eye. The method by which it gains access to the body is unknown, but presumably it is swallowed with the food, and then effects an entrance into the tissues. Once in the tissues a local inflammatory action is set up and a neoplasm is formed very similar in appearance to tubercle. Often these tubercle-like nodules break down and suppurate. In cattle there is a predilection for the disease to attack the lower jaw. It also invades the lung and sometimes the bones.

The lithographic plate (Plate IX.) contains a representation of specimens in the Museum of the Royal College of Surgeons, No. 2,274 and 2,274c. The specimens are from the tongue of an ox profoundly affected with actinomycosis. The tongue was much enlarged, protruding four or five inches from the mouth. It is excessively hard and dense. The connective tissue is much increased, in the centre a great portion of the substance is converted into a pale and to the naked eye structureless medullary mass. There are several nodules, these are most numerous in the middle of the tongue, the size of the nodules varies from that of a bean to very

minute hardly distinguishable points. The nodules are for the most part aggregated in elongated masses, which are placed between the vertical muscular fibres. The transverse section shows well the white medullary growth.

The appearance of one of the tufts when examined by the microscope is delineated in Fig. 54. They are capable of cultiva-

FIG. 54.

tion in a nutrient medium, as, for instance, peptone-gelatin, and the disease may be propagated in animals by inoculation. The writer considers it the duty of the sanitary officers to condemn as unfit for human food an animal suffering from this disease; even although the malady is in appearance localized.

(474) *Anthrax.*

Anthrax is a rapidly fatal disease, killing numbers of oxen and sheep yearly in this and other countries; it is caused by the multiplication of a bacillus, the *bacillus anthracis,* within the body.

We have here only to deal with the post-mortem characteristics. A peculiar feature of anthracoid maladies is their tendency to putrefaction even before life is extinct. Immediately after death the body of the animal often becomes immensely swollen and deformed from a large development of gas. Everywhere in the subcutaneous tissue there are infiltrations of serum, the same infiltration extends between the muscles; the muscles themselves are of a dark red, violet, or black tint, and very friable. So that in a

case of any severity, a single joint of the meat will have an entirely different naked-eye appearance to healthy meat. In different parts there may be tumours which are filled with a collection of gelatinous, citron-coloured matter, infiltrating into the subcutaneous connective and intermuscular textures and destroying the tissues; in these parts decomposition is mostly more advanced than in others. The blood is black, fluid, and stains the tissues everywhere. The heart is soft and flaccid, with hæmorrhages in its substance. There are special changes in the spleen. As a rule the spleen is enormously enlarged, sometimes ruptured, it is jet black, and from its cut surface flows a fluid which has been likened to china ink. The liver, the kidneys, the lungs, are all congested, and here and there minute hæmorrhages or larger extravasations of blood are to be seen.

A microscopical examination of the blood of the heart, or the inky fluid, or the tissue of the spleen, shows innumerable little rods; the rods vary a little in size, according to the animal from whence they have been derived; they are usually from 5–20μ long and 1–1·25μ broad; within the body they do not form spores. The rods stain intensely with aniline dyes; they are straight, or sometimes slightly curved, rigid, and have no power of self-movement. They readily admit of cultivation in feebly alkaline broth, or in nutrient gelatin, or in blood serum, or on potatoes. All the cultivations have a more or less characteristic appearance, so that a bacteriologist can in not a few cases identify the growth by examination with a low magnifying power; for instance, in a stab culture in gelatin there is first a whitish line in the track of the inoculating needle, and from it fine filaments spread out in the gelatin. Occasionally a little isolated spot develops, from which rays extend in all directions like the silky filaments of thistle-down (Crookshank). The gelatin slowly liquefies and the growth subsides as a flocculent mass. By artificial cultivations the rods may develop into threads of great length. Rods cultivated on the surface of a solid medium form spores, or if a little anthrax blood be taken and allowed to dry with free access of air, spores are formed, and once formed preserve their vitality for years. An inoculation with these spores of a small animal, such as a mouse or guinea-pig, produces death in from twenty-four to forty-eight hours. Sheep fed on potatoes, which have been the medium for cultivating the

bacillus, die in a few days. It used to be taught that pigs have an immunity from the disease, but this Prof. Crookshank has shown to be erroneous. He has produced anthrax in swine by feeding them on anthrax offal; by injection of the blood of a bullock which had died of anthrax, and by injection of artificial cultures, he has also reproduced the disease in guinea-pigs and mice by inoculation of blood from a pig which had died of anthrax.

The general and post-mortem signs of anthrax in the pig he thus describes:—

From the point of entrance of the virus there extends a yellowish jelly-like œdema of the subcutaneous areolar tissue. If the disease is induced by ingestion of anthrax offal, the tonsils are found to be ulcerated, and constitute the point of access of the bacilli to the blood. In such cases the characteristic symptom is enormous swelling around the throat. If the inoculation is by hypodermic injection, the same œdematous infiltration of the tissues occurs at the place selected for inoculation. Death may occur very rapidly in twenty-four hours, or not until five or six days. There is usually a rash-like discolouration of the skin, sometimes loss of power over the limbs, and a general weakness and disinclination to move; or the animal may lie helplessly on its belly and utter plaintive cries when disturbed. At the post-mortem the most characteristic feature is the gelatinous œdema which in the case of ingestion of offal is found around the throat. There is usually congestion of all the organs and engorgements of the heart and large vessels, fluid in the cavity of the chest and abdomen, and enlargement and hæmorrhage into the lymphatic glands. There is in some cases inflammation of the intestines, and submucous and subserous hæmorrhages. The spleen may be normal in size, pale and flabby, and the liver also only slightly congested and friable; in other cases the condition is characteristic, the spleen is the seat of hæmorrhage, causing more or less local enlargement, superficially of a deep purple colour; the liver also may be greatly congested, very friable and marked with purple patches. The examination of the blood of the heart and spleen for anthrax bacilli must be carried out with great perseverance and discrimination, as they are only present in small numbers, and in some cases have given place entirely to septic organisms. Inoculation with the blood will correspondingly produce either typical anthrax or malignant œdema.

or some other form of septicæmia. Possibly in the cases from ingestion of offal the ulcerated condition of the throat affords a nidus and means of access for septic organisms also, and it is well known that blood in a state of putrefaction may contain the bacillus of malignant œdema. In the presence of putrefactive organisms the anthrax bacillus rapidly disappears. If, therefore, inoculation of guinea-pigs or mice is used as a test for ascertaining the nature of an outbreak in swine, it must not be concluded, if Pasteur's or some other form of septicæmia result, that the disease was not anthrax; while, on the other hand, the discovery of the anthrax bacillus in the blood of the pig, or the production by inoculation of anthrax in guinea-pigs or mice with the blood of the pig, is positive evidence as to the nature of the original disease.

(475) *Charbon Symptomatique.*

This is a common epizootic in this country and the Continent; it has long been known under various names, such as *quarter ill*, black leg, and others, and has been confused with anthrax, to which it bears some resemblance. Our knowledge of the malady is derived from the researches of Arloing, Cornevin, and Thomas in France and by Dowdeswell in this country.

The disease is caused by a special micro-organism—the *clostridium of symptomatic anthrax.* The microbes are rods specially distinguished from the bacillus anthracis by being rounded at the ends and having at one end mostly a shining spore, and by being motile. The rods can be easily cultivated, but contrary to the b. anthracis they grow best with exclusion of air because they are anærobic.

The pathological signs after death differ from anthrax in at least two important characters—the spleen is neither enlarged nor black and the blood has not the black fluid appearance as in anthrax. Otherwise there is the same œdema, the same friability of the muscles, hæmorrhages into the tissues of organs, &c.

There can be no doubt of the flesh being injurious, and any animal affected with the disease should not be used for the purpose of human food. Mr. Dowdeswell remarks,[1] " In the case of

[1] "On the Ætiology of Charbon Symptomatique," by G. F. Dowdeswell. M.A., F.L.S., F.C.S., &c. *Thirteenth Annual Report of the Local Government Board, Supplement*, 1883, 1884.

rodents I have found the flesh of infected animals, *i.e.*, the tissues of the parts principally affected, to be distinctly toxical to others of the same species when eaten. Guinea-pigs, like rats, are omnivorous, and readily eat the flesh of their dead comrades however well they are supplied with other food ; in two experiments I found that giving the limb of an infected animal to another, in each case occasioned its death some days subsequently. This agrees with the accounts in this country of persons who have been poisoned, though not fatally, by eating the flesh of infected cattle."

INDEX.

INDEX.

C.

D.

W.

Y.

Z.

THE END.

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